Executive Office of the President
Office of Management and Budget

Report of the Federal Mapping Task Force on Mapping, Charting, Geodesy and Surveying July 1973

This report was prepared by an interagency task force ~~comprised~~ composed of staff of the Departments of Interior, Commerce, Agriculture, and Defense, and the Office of Management and Budget. The analyses and observations and the findings and recommendations contained herein are those of the members of the task force and do not necessarily reflect the official views of the Departments or the Office of Management ~~of~~ and Budget.

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Stock Number 2401-02426

REPORT OF THE FEDERAL MAPPING TASK FORCE
ON
MAPPING, CHARTING, GEODESY AND SURVEYING

Foreword

The last major study of Federal surveying and mapping nearly 40 years ago found a disturbing proliferation and duplication of activity among many different agencies. Today these activities are found among an even greater number, suggesting that over the years the conventional budgetary process alone could not constrain the growth of surveying and mapping outside the core agencies, which apparently were not getting the job done. Now a new generation of problems -- urban sprawl, pollution, energy crisis -- are creating additional pressures which threaten even further lag in services and diffusion of effort. This can be corrected by improving efficiency through new technology and by centralizing management, which together offer the key to a better ratio of expenditure to service.

Following President Nixon's initiatives which led to the consolidation of Department of Defense mapping, charting, and geodesy (MC&G) into the Defense Mapping Agency, the Director of the Office of Management and Budget established the Federal Mapping Task Force to study civilian MC&G requirements, operations, products, and methods.

We were directed to:

- Examine civil-agency and military domestic mapping, and geodesy programs, related activities, and supporting research and development to determine how best to engage these resources in fulfilling requirements for maps, charts, and related data.

- Investigate ways to improve efficiency and economy of mapping and charting operations and to increase responsiveness to users' needs.

- Formulate, on the basis of findings and assessments, a comprehensive national program to meet most efficiently and effectively the present and future needs for maps, charts, and related data.

- Structure an organization best suited for conducting MC&G within the Federal Government and indicate the expected costs.

Our report goes beyond the confines of the commonly accepted definitions of mapping, charting, and geodesy and discusses the impact of MC&G on management of other Federal programs, with suggestions for optimizing that impact.

The difficulties of our task were compounded by the dramatic rapidity with which change and expansion are taking place throughout less visible elements of the MC&G community, particularly in those agencies whose management has been decentralized and in those which channel Federal funds into MC&G activities via grants to States, localities, and councils of government. Prime examples, among others, are mapping activities supporting the various programs administered by the Department of Housing and Urban Development, the Federal Highway Administration, and the Environmental Protection Agency.

In approaching our study, we created eight specialized working groups to collect data and to examine and assess well-defined areas of MC&G activity. The working groups were: Resource Identification, Requirements Analysis, Imagery and Photogrammetry, Geodesy and Surveying, Marine Surveys, Data and Information, Cartography and Printing, and Security. They held many hearings, traveled extensively to gain first-hand knowledge of activities related to their assignments, and, finally, distilled their findings into a series of reports. Throughout the period of study, we met regularly with the working groups to review their conclusions

and evaluate their recommendations. Their reports constitute the primary source material on which we based our final conclusions and recommendations. We also consulted with representatives of commercial firms engaged in cartography, marine surveys, aerial surveys, and photogrammetry to determine what skills and capabilities exist in the private sector and to elicit their views on what the Federal role in mapping and charting should be.

Finally, we sponsored two separate detailed requirement reviews getting at questions of responsiveness, completeness, and worth of major products produced by the MC&G community. Our first, directed at the producing agencies, asked them to identify their consumers and to describe in depth the degree to which products meet known requirements. Based on these responses, a detailed questionnaire was designed and submitted to selected major users seeking their evaluation of products, how necessary the products are, and what actions, if any, would be taken if the products were not forthcoming. Over 1,200 questionnaires were returned from Federal agencies, State and local governments, commercial firms, and public organizations. These questionnaires are on file and available for reference. We used this process both as a zero-base review of ongoing MC&G activities and as a take-off for determining shortcomings, overlap, and gaps.

Our initial report contained both classified and unclassified information. This edition has been prepared in unclassified form to present the major findings, conclusions, and recommendations of the study to interested readers.

To optimize clarity, we have avoided wherever possible using the technical language commonly applied within the MC&G community, recognizing that in doing so we may offend some of our readers.

Our findings indicate a need to consolidate selected functions and programs under a new strong central mapping agency. The role of this new agency as well as the job it needs to do emerge more clearly as current programs are discussed and as issues are identified and evaluated. Detailed organizational discussion is, therefore, deferred until near the end of the report.

Our proposal for MC&G reorganization is urged for immediate adoption. Although reorganization may cause some temporary dislocation in programs of agencies losing in-house MC&G capabilities, we believe it will most effectively combine capabilities to better support government programs. The incremental cost in taking prompt action for consolidation will be relatively small, but providing advanced technological capability to the civilian mapping community will cost substantially more. We believe, however, that effectiveness and savings brought about by consolidation and use of advanced technology over time will far outstrip the investment.

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ABBREVIATIONS OR ACRONYMS USED IN THIS REPORT

AEC	Atomic Energy Commission
AID	Agency for International Development
ASCS	Agricultural Stabilization and Conservation Service (Dept of Agriculture)
BIA	Bureau of Indian Affairs (Dept of Interior)
BOB	Bureau of the Budget (Now Office of Management and Budget)
BOR	Bureau of Outdoor Recreation (Dept of Interior)
BPA	Bonneville Power Administration (Dept of Interior)
BR	Bureau of Reclamation (Dept of Interior)
BSFW	Bureau of Sport Fisheries and Wildlife (Dept of Interior)
CE	Corps of Engineers (Army - Dept of Defense)
CG	Coast Guard (Dept of Transportation)
DENR	Department of Energy and Natural Resources (a proposed new Department)

DMA	Defense Mapping Agency (Dept of Defense)
DOD	Department of Defense
EDC	EROS Data Center (GS - Dept of Interior)
EDS	Environmental Data Service (NOAA - Dept of Commerce)
EPA	Environmental Protection Agency
ERL	Environmental Research Laboratories (NOAA - Dept of Commerce)
EROS	Earth Resources Observation Systems (Dept of Interior)
ERTS	Earth Resources Technology Satellite (NASA)
ESIC	Environmental Science Information Center (EDS - NOAA - Dept of Commerce)
ESL	Earth Sciences Laboratories (ERL - NOAA - Dept of Commerce)
FAA	Federal Aviation Administration (Dept of Transportation)
FCC	Federal Communications Commission
FGCC	Federal Geodetic Coordinating Committee
FHWA	Federal Highway Administration (Dept of Transportation)

FS	U.S. Forest Service (Dept of Agriculture)
FSA	Federal Survey Administration (Agency proposed by this Task Force)
GPO	Government Printing Office
GS	Geological Survey (Dept of Interior)
GSFC	Goddard Space Flight Center (NASA)
HEW	Department of Health, Education and Welfare
HUD	Department of Housing and Urban Development
IACC	Interagency Air Cartographic Committee
IDOE	International Decade of Ocean Exploration
JCP	Joint Committee on Printing (Congress)
LEAA	Law Enforcement Assistance Administration
MC&G	Mapping, Charting, and Geodesy (and related surveys)
MIO	Map Information Office (Topo Div - GS - Dept of Interior)
MRC	Mississippi River Commission (CE - Army - Dept of Defense)
MSC	Manned Spacecraft Center (NASA)

NASA	National Aeronautics and Space Administration
NAVOCEANO	Naval Oceanographic Office (Navy - Dept of Defense)
NCIC	National Cartographic Information Center
NGS	National Geodetic Survey (NOS - NOAA - Dept of Commerce)
NGSP	National Geodetic Satellite Program
NOAA	National Oceanic and Atmospheric Administration (Dept of Commerce)
NODC	National Oceanographic Data Center (EDS - NOAA - Dept of Commerce)
NOS	National Ocean Survey (NOAA - Dept of Commerce)
NPS	National Park Service (Dept of Interior)
NSF	National Science Foundation
OAESA	Oceanic, Atmospheric, and Earth Science Administration (in proposed DENR)
OCD	Office of Civil Defense (Dept of Defense)
OMB	Office of Management and Budget
ONR	Office of Naval Research (Dept of Defense)

OSP	Ocean Survey Program (Dept of Defense)
RALI	Resources and Land Information (Program of Dept of Interior)
SAO	Smithsonian Institution - Astrophysical Observatory
SCS	Soil Conservation Service (Dept of Agriculture)
SESA	Social and Economic Statistics Administration (Dept of Commerce)
TVA	Tennessee Valley Authority

OVERVIEW AND SUMMARY

A long history of Federal civilian MC&G operations by a dispersed community has produced three disturbing phenomena. One is the significant growth in uncoordinated, noncumulative, single-purpose surveys and mapping which benefit only one user agency and are therefore inefficient. The second is a growing mass of unmet national needs for products and data. The third is the inability of the community as now organized to deal efficiently and responsively with these growing and changing requirements. Said simply, the community has a job to do that must be defined better and done better with strong leadership.

Although a number of specific management improvement measures may help to bring about a closer relationship between cost and effectiveness, our main conclusion is that the community should be reorganized under central management. We fully recognize that reorganization in itself is not a panacea, but it can and would create fertile conditions in which informed and innovative leadership can flourish. Moreover, without reorganization, coordination will remain more difficult to achieve than was coordination of the Defense MC&G community prior to the establishment of the Defense Mapping Agency.

MC&G Today

In FY 1972, the total Federal expenditure for civilian and military domestic MC&G was $304.8 million in 39 agencies involving 12,946 man-years of effort (table 1). The major, most visible portions of this effort were in the multipurpose national programs of Geological Survey (GS) and National Ocean Survey (NOS). But these amounted only to $90 million and 4,300 man-years. Less visible were the MC&G support services funded to the extent of $48 million by three agencies, Department of Housing and Urban Development (HUD), Federal Highway Administration (FHWA), and the National Science Foundation (NSF). The remaining 34 agencies

TABLE 1

FEDERAL MC&G RESOURCES BY DEPARTMENT & INDEPENDENT AGENCY[1/]

(FY 1972 Expenditures in Thousands of Dollars)

Agency	Produce	Contract		Fund/ Grant	Total MC&G		Related Activities		
		Non-Federal	Federal[2/]		$	MY	$	MY	Description
EXECUTIVE OFFICE OF THE PRESIDENT									
Office of Emergency Preparedness	-	-	(130)	-	-	-	-	-	
DEPARTMENT OF STATE									
Agency for Internat'l Development		93	(749)	-	93	-	-	-	
DEPARTMENT OF DEFENSE									
Defense Mapping Agency	12,375	-	(342)	-	12,375	771	-	-	
Inter-American Geodetic Survey	3,100	-	-	-	3,100	159	-	-	
Air Weather Svc, Air Force	140	-	-	-	140	39	-	-	
Office of Naval Research	21,700	-	-	-	21,700	50	32,300	380	Oceanographic Surveys
Navy Operations	29,052	-	-	-	29,052	319	8,549	88	Oceanographic Surveys
30th Engr Battalion, US Army	127	-	-	-	127	20	-	-	
Corps of Engineers, US Army	22,881	-	-	-	22,881	1,458	-	-	
Mississippi River Comm., US Army	1,322	-	-	-	1,322	83	-	-	
TOTAL - DEFENSE	90,697		(342)		90,697	2,899	40,849	468	
DEPARTMENT OF THE INTERIOR									
Topographic Division, Geological Survey (GS)	36,639	824	(4,047)	-	37,463	1,836	-	-	
Geologic Division, GS	4,442	-	(1,375)	-	4,442	85	11,591	361	Geologic Investigations
Water Resources Division, GS	44	-	(739)	-	44	2	3,342	125	Hydrologic Investigations
Conservation Division, GS	1,123	2,120	-	-	3,243	150	-	-	
Publications Division, GS	6,031	-	-	-	6,031	342	-	-	
Earth Resources Observation Systems, GS	-	-	(1,836)		-	-	-	-	
Bureau of Land Management	11,188	50	-	-	11,238	632	-	-	
National Park Service	1,220	-	(49)	-	1,220	199	-	-	
Bureau of Reclamation	5,535	890	(64)	-	6,425	464	-	-	
Bureau of Mines	205	-	-	-	205	11	-	-	
Bur. of Sport Fisheries & Wildlife	571	-	-	-	571	46	-	-	
Bureau of Indian Affairs	3,325	21	(84)	-	3,346	278	-	-	
Bonneville Power Administration	1,078	508	-	-	1,586	98	-	-	
TOTAL - INTERIOR	71,835	4,413	(8,194)		76,248	4,156	14,933	486	
DEPARTMENT OF AGRICULTURE									
Agricultural Stabilization & Conservation Service	2,033	600	-	-	2,633	137	-	-	
Soil Conservation Service	4,952	1,554	-	-	6,506	449	21,446	1,254	Soils Delineation
Forest Service	10,889	435	(550)	-	11,324	712	2,150	97	Soils Delineation
TOTAL - AGRICULTURE	17,874	2,589	(550)		20,463	1,298	23,596	1,351	
DEPARTMENT OF COMMERCE									
Nat'l Ocean Survey, Nat'l Oceanic & Atmospheric Admin. (NOAA)	41,165	-	-	-	41,165	2,036	-	-	
Environmental Data Svc., NOAA	615	-	-	-	615	25	-	-	
Environmental Research Labs, NOAA	3,761	-	-	-	3,761	178	3,434	137	Oceanographic Surveys
Nat'l Marine Fisheries, NOAA	-	-	-	-	-	-	21,285	1,091	Oceanographic Surveys
Bureau of Census, SESA	956	-	-	-	956	82	-	-	
TOTAL - COMMERCE	46,497				46,497	2,321	24,719	1,228	
DEPARTMENT OF TRANSPORTATION									
U. S. Coast Guard	4,756	-	-	-	4,756	475	7,223	853	Oceanographic Surveys
Federal Aviation Administration	1,306	-	(3,467)	-	1,306	47	-	-	
Federal Highway Administration	-	-	-	11,007	11,007	986	-	-	
TOTAL - TRANSPORTATION	6,062		(3,467)	11,007	17,069	1,508	7,223	853	
DEPT. OF HOUSING & URBAN DEVELOPMT	-	-	-	17,240	17,240	-	-	-	
INDEPENDENT AGENCIES									
Atomic Energy Commission	1,698	20	-	-	1,718	50	-	-	
Delaware River Basin Comm.	3	-	(12)	-	3	-	-	-	
Environmental Protection Agency	-	1,506	-	-	1,506	-	-	-	
General Services Administration	416	151	-	-	567	34	-	-	
Nat'l Aeronautics & Space Admin.	7,401	-	(3,351)	-	7,401	405	-	-	
National Science Foundation	-	-	(256)	20,300	20,300	-	29,800	-	Oceanographic Surveys
Smithsonian Astrophysical Obs.	2,389	-	-	-	2,389	88	-	-	
Tennessee Valley Authority	2,794	-	-	-	2,794	185	891	52	Foreign Topographic Mapping
TOTAL - INDEPENDENT AGENCIES	14,701	1,677	(3,619)	20,300	36,678	762	30,691	52	
BILATERAL ORGANIZATIONS									
Internat'l Boundary Comm., U. S. & Canada	36	-	-	-	36	2	-	-	
Internat'l Boundary & Water Comm., U. S. & Mexico	152	22	-	-	174	13	-	-	
TOTAL - BILATERAL ORGANIZATIONS	188	22			210	15			
TOTAL	247,420	8,794	(17,051)	48,547	304,761	12,946	142,011	4,438	

1/ Includes civil mapping, charting, geodesy, surveying, and related activities and similar Department of Defense domestic and marine programs.

2/ Expenditures shown are included in producing agency totals.

spent $162 million. Except for some national program work, most of this funding was spent piecemeal -- either in-house or by contracting -- in response to problems, specific needs, program pressures, and emergencies.

But we also found that the scope of MC&G was not entirely clear cut. In addition to the $304.8 million, $142 million was spent by 11 agencies not within the core of MC&G but for activities such as oceanographic surveys, soil delineation, and geologic investigations that we felt were closely enough related to justify our attention.

The wide dispersion of Federal domestic MC&G operations among seven departments and 11 independent agencies, shown on figure 1, graphically demonstrates the lack of central management. Facilities scattered across the Nation -- 130 offices and other installations, not including offices with only a few people -- vary in size and capability (fig. 2).

How the Community Functions

Federal MC&G activities are somewhat coordinated, but they are generally marked by insularity, agency competition, some overlap, and shortfall in meeting important national needs in terms of coverage and timeliness. The Bureau of the Budget Circular A-16 (Coordination of Surveying and Mapping Activities), issued in an effort to overcome these problems, has been only partially successful. The lead agencies (NOS and GS) were not given clear mandates to search for and identify duplication nor sufficient influence to modify another agency's program meaningfully. In addition, over the years, there has been no interdepartmental overview of the entire community by either the Bureau of the Budget or the Office of Management and Budget. This has fostered fragmentation of Federal activity, and MC&G elements of other agencies' programs became progressively larger.

National programs of nautical and aeronautical charting, geodetic control, and topographic mapping produce information that serves

Figure 1

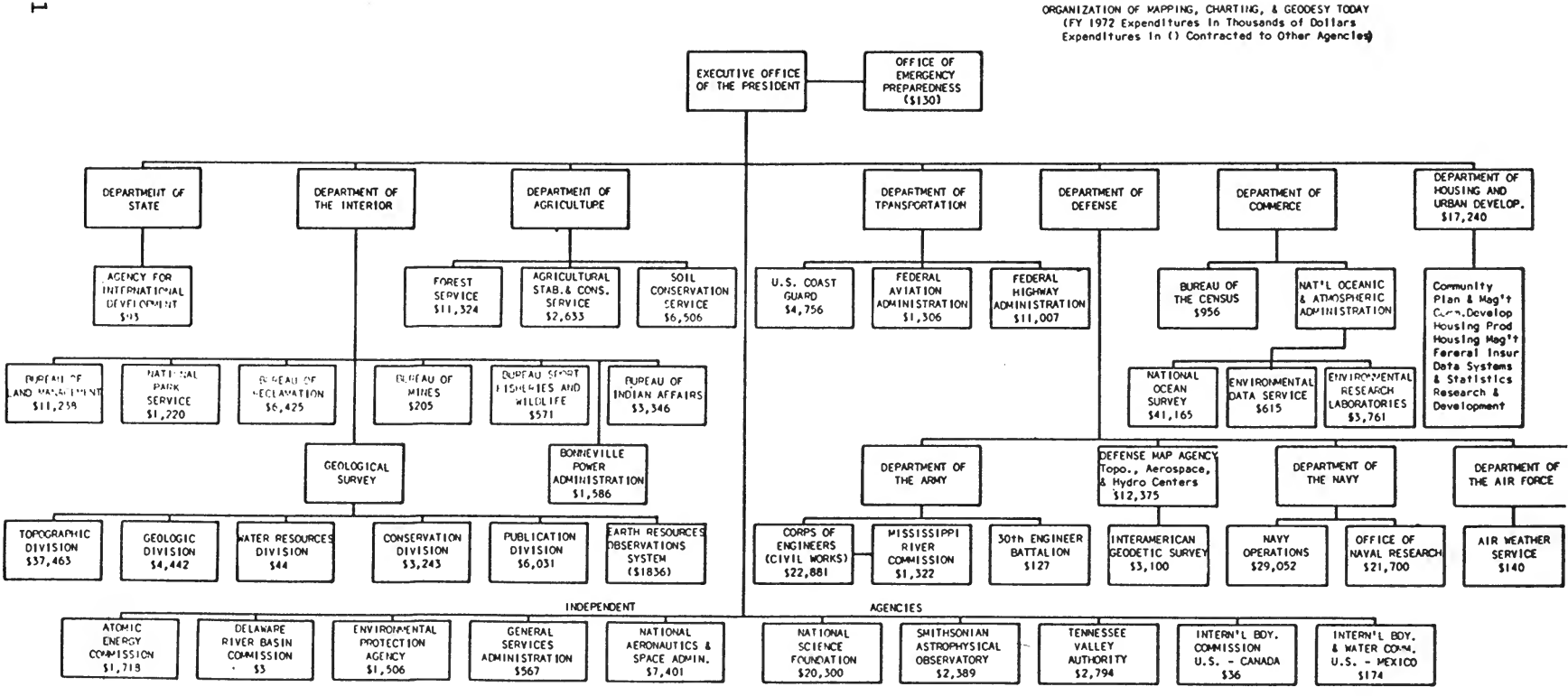
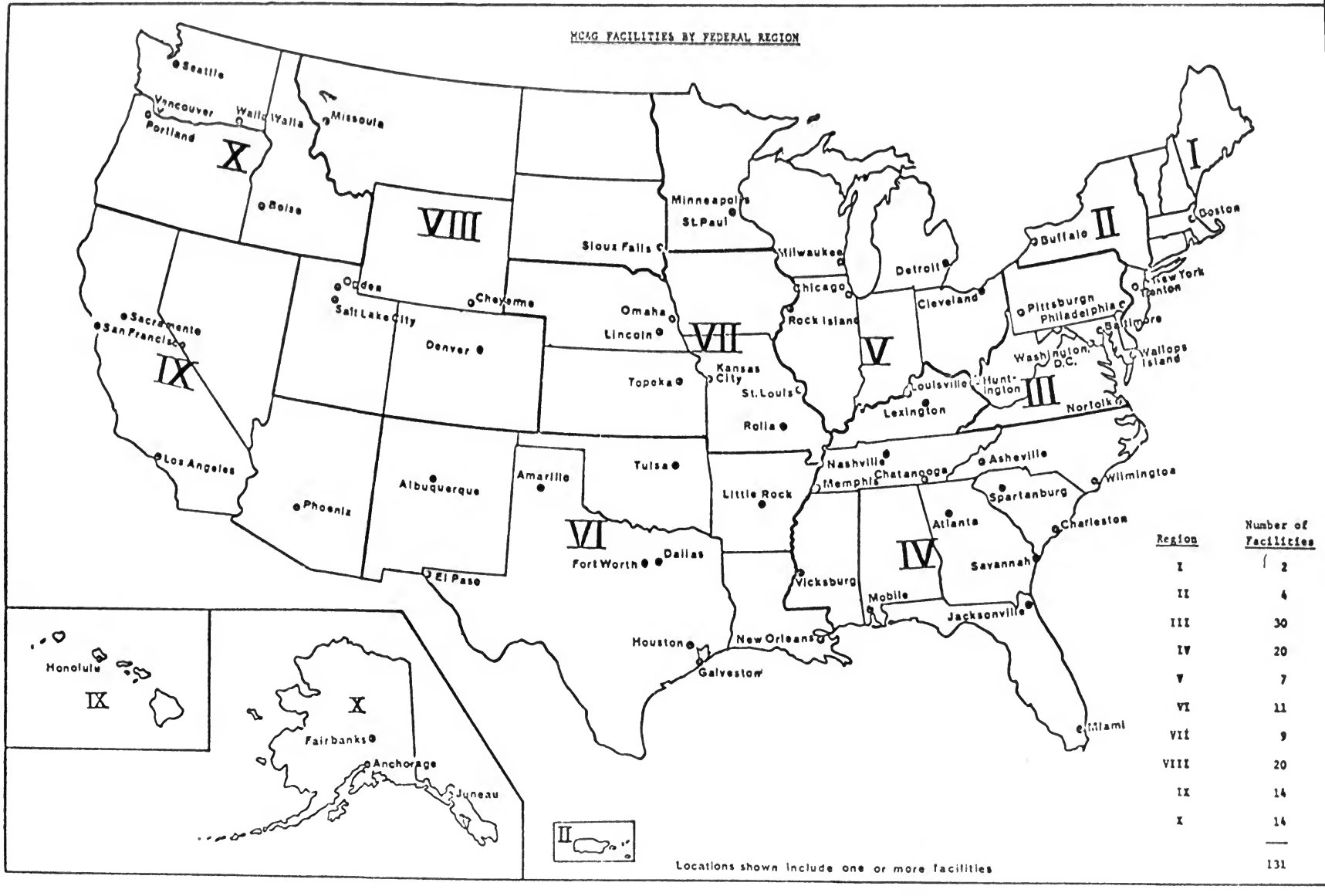

ORGANIZATION OF MAPPING, CHARTING, & GEODESY TODAY
(FY 1972 Expenditures In Thousands of Dollars
Expenditures In () Contracted to Other Agencies)
EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF EMERGENCY PREPAREDNESS ($130)
DEPARTMENT OF STATE
AGENCY FOR INTERNATIONAL DEVELOPMENT $45
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT $11,238
NATIONAL PARK SERVICE $1,220
BUREAU OF RECLAMATION $6,425
BUREAU OF MINES $205
BUREAU SPORT FISHERIES AND WILDLIFE $571
BUREAU OF INDIAN AFFAIRS $3,346
GEOLOGICAL SURVEY
TOPOGRAPHIC DIVISION $37,463
GEOLOGIC DIVISION $4,442
WATER RESOURCES DIVISION $44
CONSERVATION DIVISION $3,243
PUBLICATION DIVISION $6,031
EARTH RESOURCES OBSERVATIONS SYSTEM ($1836)
BONNEVILLE POWER ADMINISTRATION $1,586
DEPARTMENT OF AGRICULTURE
FOREST SERVICE $11,324
AGRICULTURAL STAB. & CONS. SERVICE $2,633
SOIL CONSERVATION SERVICE $6,506
DEPARTMENT OF TRANSPORTATION
U.S. COAST GUARD $4,756
FEDERAL AVIATION ADMINISTRATION $1,306
FEDERAL HIGHWAY ADMINISTRATION $11,007
DEPARTMENT OF DEFENSE
DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS (CIVIL WORKS) $22,881
MISSISSIPPI RIVER COMMISSION $1,322
30th ENGINEER BATTALION $127
DEFENSE MAP AGENCY Topo., Aerospace, & Hydro Centers $12,375
INTERAMERICAN GEODETIC SURVEY $3,100
DEPARTMENT OF THE NAVY
NAVY OPERATIONS $29,052
OFFICE OF NAVAL RESEARCH $21,700
DEPARTMENT OF THE AIR FORCE
AIR WEATHER SERVICE $140
DEPARTMENT OF COMMERCE
BUREAU OF THE CENSUS $956
NAT'L OCEANIC & ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SURVEY $41,165
ENVIRONMENTAL DATA SERVICE $615
ENVIRONMENTAL RESEARCH LABORATORIES $3,761
DEPARTMENT OF HOUSING AND URBAN DEVELOP. $17,240
Community Plan & Mag't Comm. Develop
Housing Prod
Housing Mag't
Fereral Insur
Data Systems & Statistics
Research & Development
INDEPENDENT AGENCIES
ATOMIC ENERGY COMMISSION $1,718
DELAWARE RIVER BASIN COMMISSION $3
ENVIRONMENTAL PROTECTION AGENCY $1,506
GENERAL SERVICES ADMINISTRATION $567
NATIONAL AERONAUTICS & SPACE ADMIN. $7,401
NATIONAL SCIENCE FOUNDATION $20,300
SMITHSONIAN ASTROPHYSICAL OBSERVATORY $2,389
TENNESSEE VALLEY AUTHORITY $2,794
INTERN'L BDY. COMMISSION U.S. - CANADA $36
INTERN'L BDY. & WATER COMM. U.S. - MEXICO $174

Figure 2



Region	Number of Facilities
I	2
II	4
III	30
IV	20
V	7
VI	11
VII	9
VIII	20
IX	14
X	14
	131

common needs of Federal agencies, State and local governments, and the general public. Thus these programs are clearly the responsibility of the Federal Government.

Aeronautical and nautical charting programs are necessary for the safe management of U.S. airspace and navigable waters. We have found the products to be highly responsive as vehicles for communicating information essential to air and marine navigation, but we believe both programs can benefit from advancements in automation. Although both NOS and DOD engage in aeronautical charting, there are no serious problems of overlap, and no other Federal agencies have competitive chart-production capability.

The fundamental geodetic networks have become incomplete through obsolescence and need new surveys and a new national adjustment to meet modern demands. The integration of the basic cadastral networks of Federal lands with the horizontal geodetic network would be very beneficial. Early application of this integration is proposed for Alaska, where needed surveys for the transfer of Federal lands to the State could be done much faster and cheaper.

Unlike the aeronautical and nautical charting programs, land mapping and surveying programs are far more diverse, serving a broader range of functions. Because of this, and the inadequate rate of production, agencies other than GS and NOS have developed duplicative in-house programs. There is a basic dependence on geodetic control and topographic maps -- as experienced by all advanced countries -- that will continue to be widespread and heavy. The lack of full and up-to-date coverage with basic maps and precise geodetic control, combined with the inability of the national programs to respond to immediate needs for these and related services, threatens a further development of scattered and uncoordinated in-house capabilities and private-sector contracting.

In-house MC&G capabilities demand "care and feeding" once they are developed. And so they are fed -- in perfect conformance to the principles of Parkinson's Law. This phenomenon has not gone unnoticed over the years. Numerous study groups and commissions

recognized what was happening and identified the causes, but their recommended solutions failed to come to grips with two major impediments:

- The disarray of military MC&G with two, and then three, voices speaking simultaneously to civilian agencies, often working at cross-purposes with them and with each other. In a real sense there was no community.

- An inability to identify and implement surefire innovative improvements that would bring about stepped-up delivery of surveys and maps to using agencies when and where needed resulted in continued lag in productivity in face of growing national requirements.

The first impediment was largely removed last year when, by Presidential direction, most of the Defense Department MC&G was consolidated in the Defense Mapping Agency (DMA). This corrected the problem of civilian-military coordination which perplexed the earlier study groups. Moreover, the DMA experience has already demonstrated the advantages attainable by consolidation and is an example of a working management improvement.

The second impediment can now be resolved by applying DOD advanced technology against civilian requirements, thereby providing a way for national MC&G programs to achieve responsiveness and greater effectiveness. Present methods and technology cannot meet the requirements of civilian MC&G programs.

But advanced technology has not been aggressively explored by the civilian community. Its potential benefits are not being realized and dozens of uses have been ignored or overlooked. The lack of civilian MC&G involvement has been accompanied by development of expensive systems for civilian use that cannot compete in any meaningful way with DOD-developed techniques. Failing to adapt to new technology will mean continued pressure for redundant and less efficient systems.

Other problem areas were revealed by our study of Federal MC&G activities:

- No mechanism exists in the civilian community for the orderly identification and validation of all national MC&G requirements because there has been a lack of a dynamic community approach to them, and therefore production capabilities are insufficiently geared to respond to changing requirements. A central requirements organization must be established, staffed sufficiently to seek for, evaluate, and weigh requirements and feed this information to the production centers.

- R&D effort is small and fragmented and has not fully explored or exploited the applicability of DOD-developed technology to civilian programs. A formal collective arrangement is needed for identification of civilian requirements that can then be integrated with ongoing or planned Defense R&D, and when appropriate, to merge civilian and DOD procurement.

- Map and chart printing has been handicapped by a curious, overly rigid congressional chokehold. Although product distribution is adequately handled in individual areas, the overall effort lacks optimal effectiveness because of the lack of a central clearing house for products and limited use of modern merchandising techniques.

- Pricing policy for government sales of maps, charts, and related publications to the public is not consistent. Substantial additional revenue can be obtained by

adoption of a standardized formula for determining prices and collecting revenues.

- Among urgent unmet needs is one for a rationalization of community activities for data and information systems. Separate systems using a variety of reference bases are being established with little or no correlation at great cost. Users of MC&G data now must query many different locations for assurance that they have all the official data available for their areas of interest. A central data information facility is needed to access, evaluate, store, retrieve, and disseminate Federal holdings of imagery, geodetic and survey control, maps, charts, and spatially-related data on a common reference base.

- Another major unmet need is that of a national urban surveying and mapping program to support a host of Federal programs involved in the development of urban areas. A major HUD official outlined the need for "direction in developing a common mapping methodology which could be used uniformly by all Federal agencies and A-95 clearing houses serving the Nation's communities and also meeting their own mapping requirements." What is needed is a national-scale urban mapping and surveying effort with clearly defined Federal standards. The mapping should be accomplished by commercial firms under contracts monitored by the responsible Federal MC&G agency.

- Private cartographic contract capability is not being used sufficiently. We found this capacity to be broad and varied and capable of rendering skilled support to Federal MC&G programs. Contract capability is a viable management alternative, and using it would be consistent with the President's desire to limit the size of the Federal payroll.

Its use should be encouraged in lieu of continued in-house buildup.

- The marine geophysics and oceanographic programs operated by NOAA, Coast Guard, and Navy, and those funded by the National Science Foundation are not sufficiently coordinated. Classified data collected by the Navy often are unavailable. (even sanitized) to the civilian agencies.

In addition to these problems, we found that proliferation of MC&G capability is a continuing process. It was aptly described to us by the Administrator of the Environmental Protection Agency when he wrote:

- His agency now has only a modest MC&G program and

- He intends to use existing Federal MC&G capabilities to the extent possible in meeting requirements but

- He envisages the need for greater in-house capability to take care of needs not satisfied by the national programs.

Clearly, EPA and others like it have indisputable requirements for surveying and mapping. Building in-house capacity, however, is not the answer, and, if history and current experience tell anything at all, neither is reliance on the community as presently structured and managed. What is needed is a totally new concept.

Reorganization

We believe that Federal civilian MC&G resources can be made more productive by a community reorganization based on:

- Establishing a comprehensive and integrated program to provide multipurpose products.

- Setting up a more effective mechanism to determine user requirements and assure a satisfactory level of response.

- Combining existing resources into a larger base that can make greater use of advanced technology which must be capitalized.

Our proposed central civilian agency would have well-defined authority to manage and coordinate the entire civilian Federal MC&G community in order to undertake these actions. Basic national MC&G programs and MC&G activities that are potentially systematic and multipurpose would be transferred intact to form the nucleus of the new agency. The new agency must be of size and scope commensurate with the magnitude, importance, and complexity of the services it must render, and it must be given sufficient clout to arrest and reduce needless proliferation of MC&G activities outside the national programs. Such an organization can give adherence and leadership and assure flexibility to meet new needs as they are identified.

National and agency-oriented programs and their problem areas are further discussed in later sections of this report, together with relevant suggestions for management improvement. Budgetary impacts of the major suggestions are shown on table 2. The MC&G activities are grouped under three main general categories (table 3) and are discussed in sections as follows:

- Land Surveys -- includes geodetic surveys, cadastral surveys, and other spatial positioning activities.

- Land Mapping -- includes topographic, planimetric, and thematic mapping and aeronautical charting.

- Marine Mapping and Charting and Related Surveys -- includes nautical charting, bathymetric mapping, geophysical/geological surveys, and platform related surveys.

TABLE 2
EFFECTS OF MANAGEMENT IMPROVEMENTS
($ in Millions)

Recommended Actions	Average annual expenditure change and source of funds				Estimated average annual savings			Estimated average annual cost avoidance			Remarks
	1974-78		1979-83								
	Capital outlay	Reallo-cation	Capital outlay	Reallo-cation	1974-1978	1979-1983	Outyear rate	1974-1978	1979-1983	Outyear rate	
Accomplish new adjustment of horizontal control network.	1.3	0.4	--	0.4	--	0.2	increases to 1.4	--	1.5	increases to 5.0 in 1990	Reallocated funds from National Geodetic Program. Savings from avoidance of piecemeal adjustment, duplicative data handling and surveys.
Provide multi-purpose surveys in urban areas, double the national vertical control program, coordinate local surveys, and expand control data base.	--	2.3	--	2.3	0.5	3.0	increases	--	--	--	Funds reallocated from HUD supported surveys, and from other Federal land survey programs. Savings from reducing duplicative and single purpose surveys.
Combine appropriate cadastral surveys with geodetic surveys, especially in Alaska.	--	--	--	--	0.3	0.3	same	1.6	1.6	same	Functions merged with no increase in funding. Savings from increased efficiency and dual purpose surveys. Cost avoidance from doing the job faster in Alaska.
Use classified data and advanced technology in production of most topographic, planimetric, and related products.	1.0	--	--	--	0.5	2.2 to 6.2 *	increases to 4.0 or to 8.0 *	--	--	--	Capitalization includes analytical mensuration and compilation equipment. Savings from reduced field checking, control surveys, photography.
Expand use of classified data for interim revision of 1:24,000 maps	--	--	--	--	.3	.3	same	--	--	--	
Combine cartographic resources of land-management agencies in production of special base maps.	--	--	--	--	.1	.1	same	--	--	--	Savings from improved efficiency, uniform standards and reduction in duplication.
Automate aeronautical chart production.	0.6	--	--	--	0.2	0.5	increases	--	--	--	Additional resources for development of automated techniques and equipment purchase. Savings come from reduced manpower.
Accelerate nautical chart production by implementing shore based operations and automated data handling.	1.5	--	--	--	0.4	1.0	increases	0.8	2.0	increases	Additional resources for new equipment. Savings from more efficient chart production. Cost avoidance from redeployment of ships.
Centralize management of printing and distribution.	--	--	--	--	0.5	1.0	same	--	--	--	Savings from more effective use of presses and distribution facilities.
Increase map and chart prices.	--	--	--	--	4.7	4.7	same	--	--	--	Increased revenue.
Totals	4.4	2.7	--	2.7	7.5	13.3 to 17.3 *	----	2.4	5.1	--	* High side of estimate is contingent on declassification of data.

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TABLE 3

FEDERAL MC&G RESOURCES BY MAJOR PURPOSE

(FY 1972 Expenditures in Thousands of Dollars. Resources Shown in () Contracted to Other Agencies.)

Agency	Land Surveys			Land Mapping and Aeronautical Charting			Marine Mapping, Charting & Surveying			Total			Related Activities		
	$		MY	$		MY	$		MY	$		MY	$	MY	Description
EXECUTIVE OFFICE OF THE PRESIDENT															
Office of Emergency Preparedness	-	(130)	-	-		-	-		-	-	(130)	-	-	-	
DEPARTMENT OF STATE															
Agency for International Development	-		-	93	(749)	-	-		-	93	(749)	-	-	-	
DEPARTMENT OF DEFENSE															
Defense Mapping Agency	4,070		335	8,305		436	-	(342)	-	12,375	(342)	771	-	-	
Inter-American Geodetic Survey	1,000		53	2,100		106	-		-	3,100		159	-	-	
Air Weather Service, U. S. Air Force	-		-	140		39	-		-	140		39	-	-	
Office of Naval Research	-		-	-		-	21,700		50	21,700		50	32,300	380	Oceanographic Surveys
Navy Operations	-		-	-		-	29,052		319	29,052		319	8,549	88	Oceanographic Surveys
30th Engineer Battalion, U. S. Army	127		20	-		-	-		-	127		20	-	-	
Corps of Engineers, U. S. Army	11,856		774	4,326		288	6,699		396	22,881		1,458	-	-	
Mississippi River Commission, U. S. Army	324		19	423		29	575		35	1,322		83	-	-	
TOTAL - DEFENSE	17,377		1,201	15,294		898	58,026	(342)	800	90,697	(342)	2,899	40,849	468	
DEPARTMENT OF THE INTERIOR															
Topographic Division, Geological Survey (GS)	6,377		337	31,086	(4,047)	1,499	-		-	37,463	(4,047)	1,836	-	-	
Geologic Division, GS	930		16	222	(1,375)	10	3,290		59	4,442	(1,375)	85	11,591	361	Geologic Investigations
Water Resources Division, GS	-		-	44	(739)	2	-		-	44	(739)	2	3,342	125	Hydrologic Investigations
Conservation Division, GS	-		-	-		-	3,243		150	3,243		150	-	-	
Earth Resources Observation Systems, GS	-		-	-	(1,836)	-	-		-	-	(1,836)	-	-	-	
Publications Division, GS	-		-	6,031		342	-		-	6,031		342	-	-	
Bureau of Land Management	8,627		433	2,611		199	-		-	11,238		632	-	-	
National Park Service	255	(49)	44	965		155	-		-	1,220	(49)	199	-	-	
Bureau of Reclamation	5,212	(64)	411	1,051		41	162		12	6,425	(64)	464	-	-	
Bureau of Mines	-		-	205		11	-		-	205		11	-	-	
Bureau of Sport Fisheries & Wildlife	458		35	113		11	-		-	571		46	-	-	
Bureau of Indian Affairs	3,250	(84)	270	96		8	-		-	3,346	(84)	278	-	-	
Bonneville Power Administration	874		33	712		65	-		-	1,586		98	-	-	
TOTAL - INTERIOR	25,983	(197)	1,579	43,136	(7,997)	2,343	6,695		221	75,814	(8,194)	4,143	14,933	486	
DEPARTMENT OF AGRICULTURE															
Agricultural Stabilization & Conservation Service	-		-	2,633		137	-		-	2,633		137	-	-	
Soil Conservation Service	590		63	5,916		386	-		-	6,506		449	21,446	1,254	Soils Delineation
Forest Service	6,790	(535)	447	4,534	(15)	265	-		-	11,324	(550)	712	2,140	97	Soils Delineation
TOTAL - AGRICULTURE	7,380	(535)	510	13,083	(15)	788				20,463	(550)	1,298	23,596	1,351	
DEPARTMENT OF COMMERCE															
National Ocean Survey, National Oceanic & Atmospheric Administration (NOAA)	8,722		395	8,952		493	23,491		1,148	41,165		2,036	-	-	
Environmental Data Service, NOAA	490		20	-		-	125		5	615		25	-	-	
Environmental Research Laboratories, NOAA	244		7	140		5	3,377		166	3,761		178	3,434	137	Oceanographic Surveys
National Marine Fisheries, NOAA	-		-	-		-	-		-	-		-	21,285	1,091	Oceanographic Surveys
Bureau of the Census, SESA	-		-	956		82	-		-	956		82	-	-	
TOTAL COMMERCE	9,456		422	10,048		580	26,993		1,319	46,497		2,321	24,719	1,228	
DEPARTMENT OF TRANSPORTATION															
U. S. Coast Guard	-		-	-		-	4,756		475	4,756		475	7,223	853	Oceanographic Surveys
Federal Aviation Administration		(21)	-	1,306	(3,446)	47	-		-	1,306	(3,467)	47	-	-	
Federal Highway Administration	3,203		277	7,804		709	-		-	11,007		986	-	-	
TOTAL - TRANSPORTATION	3,203	(21)	277	9,110	(3,446)	756	4,756		475	17,069	(3,467)	1,508	7,223	853	
DEPARTMENT OF HOUSING & URBAN DEVELOPMENT	3,448		-	13,792		-	-		-	17,240		-	-	-	
INDEPENDENT AGENCIES															
Atomic Energy Commission	1,350		27	278		22	90		1	1,718		50	-	-	
Delaware River Basin Commission	-		-	3	(12)	-	-		-	3	(12)	-	-	-	
Environmental Protection Agency	-		-	1,506		-	-		-	1,506		-	-	-	
General Services Administration	151		-	416		34	-		-	567		34	-	-	
National Aeronautics and Space Administration	2,926	(2,484)	82	4,475	(867)	323	-		-	7,401	(3,351)	405	-	-	
National Science Foundation	-	(99)	-	-	(157)	-	20,300		-	20,300	(256)	-	29,800	-	Oceanographic Surveys
Smithsonian Astrophysical Observatory	2,389		88	-		-	-		-	2,389		88	-	-	
Tennessee Valley Authority	1,031		79	1,654		100	109		6	2,794		185	891	52	Foreign Topographic Mapping
TOTAL - INDEPENDENT AGENCIES	7,847	(2,583)	276	8,332	(1,036)	479	20,499		7	36,678	(3,619)	762	30,691	52	
BILATERAL ORGANIZATIONS															
International Boundary Comm., U. S. & Canada	36		2	-		-	-		-	36		2	-	-	
Internat'l Boundary & Water Comm., U. S. & Mexico	167		13	7		-	-		-	174		13	-	-	
TOTAL - BILATERAL ORGANIZATIONS	203		15	7						210		15			
TOTAL	74,897	(3,466)	4,280	112,895	(13,243)	5,844	116,969	(342)	2,822	304,761	(17,051)	12,946	142,011	4,438	

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LAND SURVEYS

In FY 1972, 28 Federal agencies spent $75 million and employed 4,300 personnel for domestic and foreign nonmilitary land surveys and related activities (table 4). These land surveys include those activities which are national in scope or cover large areas and meet multipurpose needs as well as activities which are local in extent and normally satisfy only single-purpose needs. This seemingly wide range of activities was considered as a unit because of the use of like survey equipment and techniques, interdependence of data, and organizational relationships. For purposes of description and review, the land surveys were grouped into the following major programs or program categories: National Geodetic Program, Geophysical Programs, Cadastral Surveys, and Facility and Mapping Control Surveys.

From the early stages of our study, several major questions concerning surveys were expressed:

- What should be the Federal level of effort in land surveys?
- Can advanced techniques be applied to increase effectiveness and efficiency?
- Should geodetic surveys and cadastral surveys be conducted separately?
- How can better use be made of single-purpose surveys?

To answer these questions, we examined land-survey requirements, current survey techniques and procedures, and the products and services.

In the following pages, each of the programs or program categories is treated in terms of objectives, requirements, agencies involved, and productivity. Additionally, pertinent issues are discussed, and conclusions and recommendations are given.

TABLE 4

FEDERAL LAND SURVEY ACTIVITIES BY PURPOSE

(FY 1972 Expenditures in Thousands of Dollars.
Resources Shown in () Contracted to Other Agencies.)

Agency	Geodetic		Earth Physics		Geophysical		Mapping Control		Cadastral		Construction & Facility		Total		
	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY	$		MY
EXECUTIVE OFFICE OF THE PRESIDENT															
Office of Emergency Preparedness	- (130)	-	-	-	-	-	-	-	-	-	-	-	-	(130)	-
DEPARTMENT OF DEFENSE															
Defense Mapping Agency	244	15	147	10	1,186	91	8	-	-	-	2,485	219	4,070		335
Inter-American Geodetic Survey	-	-	-	-	-	-	1,000	53	-	-	-	-	1,000		53
30th Engineer Battalion, U. S. Army	-	-	-	-	-	-	-	-	-	-	127	20	127		20
Corps of Engineers, U. S. Army	653	46	-	-	-	-	1,478	102	2,906	187	6,819	439	11,856		774
Mississippi River Commission, U. S. Army	-	-	-	-	-	-	-	-	97	7	227	12	324		19
TOTAL - DEFENSE	897	61	147	10	1,186	91	2,486	155	3,003	194	9,658	690	17,377		1,201
DEPARTMENT OF THE INTERIOR															
Topographic Division, Geological Survey (GS)	476	23	-	-	-	-	5,901	314	-	-	-	-	6,377		337
Geologic Division, GS	-	-	-	-	930	16	-	-	-	-	-	-	930		16
Bureau of Land Management	-	-	-	-	-	-	-	-	8,627	433	-	-	8,627		433
National Park Service	-	-	-	-	-	-	-	-	24 (49)	2	231	42	255	(49)	44
Bureau of Reclamation	372	30	-	-	-	-	-	-	611 (64)	43	4,229	338	5,212	(64)	411
Bureau of Sport Fisheries & Wildlife	-	-	-	-	-	-	-	-	458	35	-	-	458		35
Bureau of Indian Affairs	-	-	-	-	-	-	-	-	- (84)	-	3,250	270	3,250	(84)	270
Bonneville Power Administration	141	9	-	-	-	-	-	-	-	-	733	24	874		33
TOTAL - INTERIOR	989	62			930	16	5,901	314	9,720 (197)	513	8,443	674	25,983	(197)	1,579
DEPARTMENT OF AGRICULTURE															
Soil Conservation Service	-	-	-	-	-	-	-	-	-	-	590	63	590		63
Forest Service	-	-	-	-	-	-	80	9	417 (535)	48	6,293	390	6,790	(535)	447
TOTAL - AGRICULTURE							80	9	417 (535)	48	6,883	453	7,380	(535)	510
DEPARTMENT OF COMMERCE															
National Ocean Survey, National Oceanic and Atmospheric Administration (NOAA)	6,041	275	1,742	68	227	9	712	43	-	-	-	-	8,722		395
Environmental Data Service, NOAA	-	-	-	-	490	20	-	-	-	-	-	-	490		20
Environmental Research Laboratories, NOAA	-	-	219	6	25	1	-	-	-	-	-	-	244		7
TOTAL - COMMERCE	6,041	275	1,961	74	742	30	712	43					9,456		422
DEPARTMENT OF TRANSPORTATION															
Federal Aviation Administration	- (21)	-	-	-	-	-	-	-	-	-	-		-	(21)	-
Federal Highway Administration	1,132	98	-	-	-	-	-	-	235	19	1,836	160	3,203		277
TOTAL - TRANSPORTATION	1,132 (21)	98							235	19	1,836	160	3,203	(21)	277
DEPARTMENT OF HOUSING & URBAN DEVELOPMENT	-	-	-	-	-	-	1,500	-	500	-	1,448	-	3,448		-
INDEPENDENT AGENCIES															
Atomic Energy Commission	-	-	-	-	357	2	-	-	-	-	993	25	1,350		27
General Services Administration	-	-	-	-	-	-	-	-	-	-	151	-	151		-
National Aeronautics & Space Administration	-	-	2,926 (2,484)	82	-	-	-	-	-	-	-	-	2,926	(2,484)	82
National Science Foundation	-	-	-	-	-	-	- (99)	-	-	-	-	-	-	(99)	-
Smithsonian Astrophysical Observatory	-	-	2,314	87	-	-	-	-	-	-	75	1	2,389		88
Tennessee Valley Authority	-	-	-	-	57	3	57	3	248	16	669	57	1,031		79
TOTAL - INDEPENDENT AGENCIES			5,240 (2,484)	169	414	5	57 (99)	3	248	16	1,888	83	7,847	(2,583)	276
BILATERAL ORGANIZATIONS															
International Boundary Commission, U. S. & Canada	36	2	-	-	-	-	-	-	-	-	-	-	36		2
Internat'l Boundary & Water Commission, U. S. & Mexico	-	-	-	-	-	-	-	-	-	-	167	13	167		13
TOTAL - BILATERAL ORGANIZATIONS	36	2									167	13	203		15
TOTAL	9,095 (151)	498	7,348 (2,484)	253	3,272	142	10,736 (99)	524	14,123 (732)	790	30,323	2,073	74,897	(3,466)	4,280

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NATIONAL GEODETIC PROGRAM

Geodesy provides a foundation framework -- a reference system of control points -- required for many activities which demand precise locations or measurements on the earth's surface. Assessing its importance and value is almost as difficult as placing a worth on the ubiquitous match. No one phosphorous match has any significant value, yet a number of national governments have thought enough of the collective value of matches to make their production a national monopoly. So it is with geodesy. No local survey by itself can be said to have any national significance. But as many surveys develop into regional nets, and when large projects (e.g., the Federal interstate highway system) extend over large areas, then relationships between different surveys cascade over many years, creating problems that can only be resolved by the Federal Government. Accuracy standards have varied in time and in instrumentation and methods. Only the Federal Government can provide -- as have indeed the central governments of all advanced countries -- the essential foundation of systematic programming, rigorous standards, and continuity to maintain practical order in a basic element of economic development that otherwise would be hindered by the chaos of uncoordinated private (local) endeavor.

Geodesy not only serves primary economic needs, but as a science it draws on the knowledge and rigor of three basic disciplines -- astronomy, mathematics, and physics -- and in turn serves them and other earth sciences through its unique discoveries. Thus geodesy, which studies the size and shape of the earth, supports a broad range of applications, from local surveys, to mapping of all kinds, to the study of the dynamics of the earth as a whole (earthquakes, crustal movement), and ultimately to predictions of various convulsive terrestrial phenomena.

The Federal Government has been involved in the development of national geodetic networks almost from the beginning of its history and established the National Geodetic Program to meet national needs. Operations include the establishment of control stations

(recoverable marks identifying known positions and/or elevations) on a consistent nationwide reference system (datum), gravity and astronomic observations, studies of movements in the earth's crust, and the publication and distribution of data. Geodetic horizontal (i.e., latitude and longitude) data and geodetic vertical (elevation) data are the foundations of the National Geodetic Control Networks.

In FY 1972, eight Federal agencies employing 500 people accomplished or provided funding for geodetic surveys which contributed to either the horizontal or vertical geodetic control networks. BOB Circular A-16 (Revised), dated May 6, 1967, assigned the responsibility for the National Geodetic Control Networks to the Department of Commerce, which, in turn, has delegated it to NOAA. In meeting its responsibilities, NOAA, through NOS, operates a field and office force to establish points and maintain control marks and to maintain and publish information related to the national networks. Through A-16, NOAA is also charged to provide governmentwide leadership in assuring coordinated planning and execution of control surveys of Federal agencies so that appropriate surveys contribute to the national program. NOAA has established and chairs a Federal Geodetic Coordinating Committee (FGCC), composed of representatives from Federal agencies having major requirements for control, to aid in carrying out these reponsibilities.

Federal coordination of geodetic control has been successful in some instances. For example, the Topographic Division, GS, now establishes second-order control as part of the mapping process in areas where network control is needed. The GS data are given to NOS for adjustment into the national network. Also, FHWA encourages the establishment of geodetic control by States as part of highway planning and construction operations. DMA, CE, and other Federal agencies have also contributed significant amounts of data. Even though some 1,100 stations a year are added to the network by organizations other than NOAA, we consider FGCC as only partially successful. Participation is voluntary, and

many agencies refuse to incur the additional expenditures for monumentation and documentation required for entering their data into the national networks. Also, FGCC has not dealt with the coordination of control other than first- and second-order. We feel that some of the lower-order control is valuable for future use and should be documented and maintained.

We recommend expansion of the National Geodetic Data Base to include selective control of less than second-order accuracy.

This subject is discussed further in the appropriate section of this report.

Federal agency requirements for both horizontal and vertical control are submitted to NOS in accordance with Circular A-16. Combined Federal requirements should, in theory, be the determining factor in allocating survey resources. In general, the decision on where control is to be established in a given year is made on the basis of combined Federal needs, although the priority scheme is occasionally impacted by bilateral agreements with States, counties, or local governments (cooperative programs). Under these agreements, NOS does the work and receives reimbursement from the cooperator for a percentage of the project cost dependent on the ratio of Federal vs. local requirements in the area (usually 50 percent).

These cooperative programs have the undesirable effect of concentrating surveys in areas that may have lower national priorities than other areas. On the other hand, the cooperative funds substantially increase the capacity of the national effort and expand the control network at less cost to the Federal government. We believe, therefore, that cooperative programs can help meet overall national needs if they are properly managed and dovetailed with the national effort so that no high-priority Federal requirement is neglected.

We recommend continuance of cooperative programs as long as they can be effective in advancing the National Geodetic Program and do not result in the neglect of high-priority Federal needs.

Horizontal Control

The fundamental objective of the horizontal geodetic control program is to provide and maintain a nationwide network at necessary spacing and accuracy to meet Federal program needs. The network consists of approximately 125,000 monumented positions referenced to the 1927 North American Datum and has been built up year by year for more than a century.

The horizontal control network is analogous to the steel frame of a large building. Local, less accurate surveys are strengthened and related to other surveys by a framework of progressively higher accuracies and wider spacing between control arcs just as the interior framing of a building is supported by the main structure. The backbone of the network (building structure) is the transcontinental traverse, accurate to 1 part in 1,000,000 (1 ft. of error in approximately 200 miles) between any two stations along the traverse, with an average spacing of 400 miles between traverse lines. This is braced by primary triangulation arcs and traverses (framing) accurate to 1 part in 100,000 (1 ft. of error in approximately 20 miles) with an average spacing of 25 to 50 miles between surveys. Area coverage (interior partitioning) is provided at accuracy suitable for general-purpose use (1:10,000 to 1:50,000) and spacing needed to meet current or expected requirements for that area.

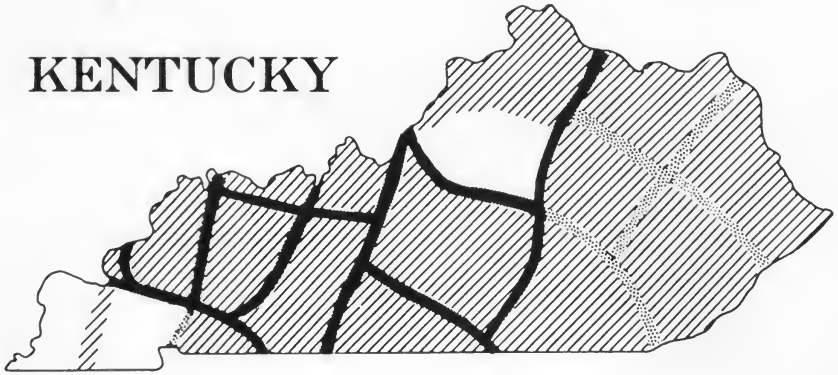
All of the country is not equally densified. Figure 3 shows an example of the disparity in area coverage: Kentucky with nearly full area coverage, and Georgia with sparse coverage. Approximately 40 percent of the U.S. is covered with area control which meets accuracy and spacing requirements for general-purpose needs (see fig 4). The question of what, if anything, the Federal Government should do to provide control in urban areas is an important issue (discussed in the following section - Requirements).

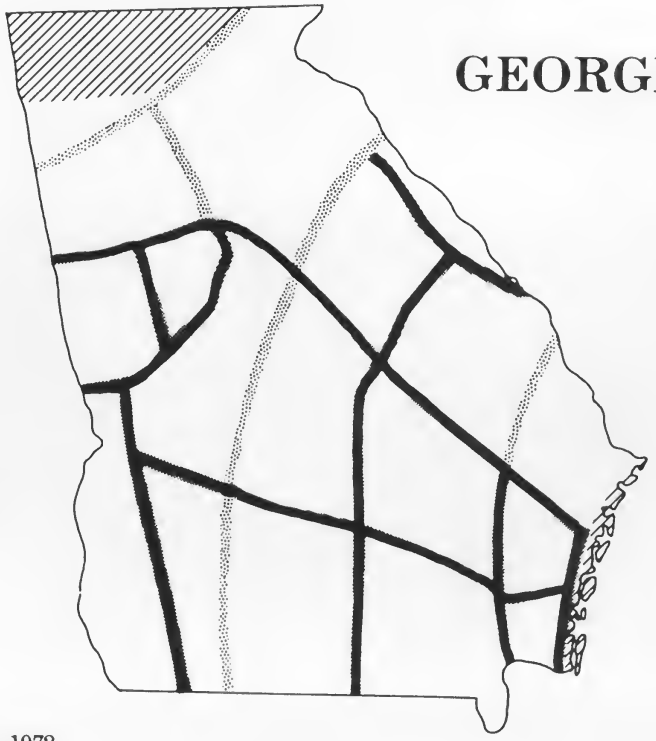
A second important issue concerns the maintenance and efficient use of the basic horizontal framework. To preserve or maintain monuments established over the years requires a vigorous recovery and repair program. And although the basic horizontal framework is

Figure 3

NATIONAL GEODETIC PROGRAM

EXISTING HORIZONTAL CONTROL in KENTUCKY and GEORGIA





Primary control completed

Additional primary control required

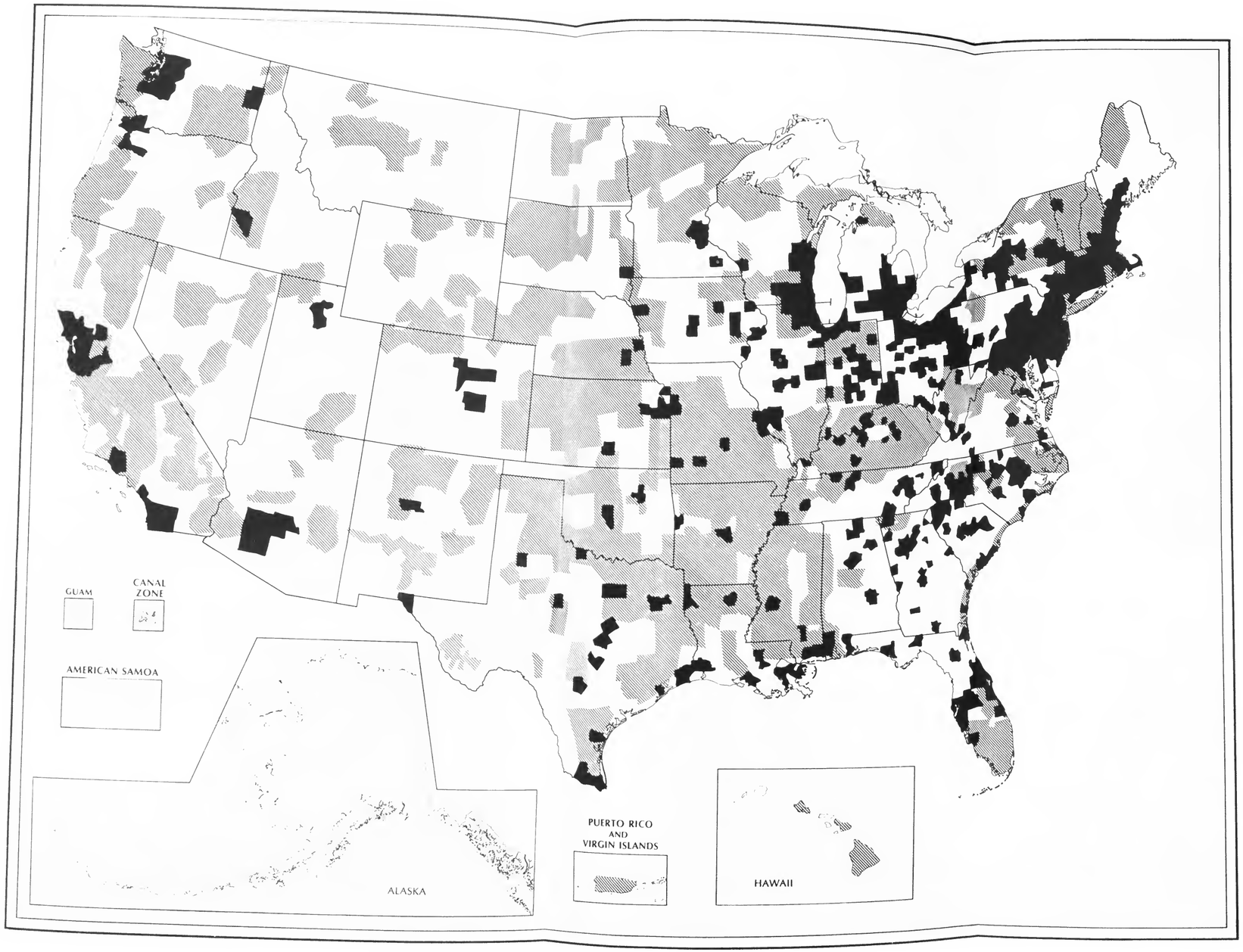
Area control completed

Area control needed

Note: Kentucky is an example of a state in which most objectives of the national program have been met.

Several primary arcs of triangulation (or traverse) are required in Georgia and most of the state requires network area control.

June 1972



NATIONAL GEODETIC PROGRAM

HORIZONTAL AREA CONTROL

Areas where accuracy and spacing requirements are met.

Areas of intensive economic development where accuracy and spacing requirements are not met.

June 1972

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Figure 4

in respectable shape insofar as the quantity of monuments is concerned, it now needs adjustment to relate monuments accurately to each other -- and to the figure of the earth -- so that new precise surveys can be tied to existing monuments without piecemeal adjustments. The need for a new adjustment is discussed under the heading North American Datum.

Requirements.--Based on our requirements review, we have identified a large number of users of horizontal control in Federal, State, and local government agencies, industry and commerce, and the public. Included among these by percentage are:

- Federal agencies (47%) -- mapping and charting by GS, NOS, FS, TVA, SCS, and CE; highway and facility construction by FHWA, FS, CE and BR; the operation and testing of Defense weapon systems; and water resource studies and flood control projects of CE, GS, SCS, and HUD.

- State and local governments (17%) -- planning and construction of streets and highways; regional and urban planning and development; water resource studies and flood control; determination of boundaries and political subdivisions.

- Industry and commerce (17%) -- surveying and mapping projects, mineral exploration, transportation, utilities, and communications projects.

- General public (19%) -- college and university research and training projects and local surveys.

Insofar as Federal agency needs for control are concerned, our requirements questionnaires conclusively documented that if control is not available or immediately forthcoming from the National Geodetic Program, agencies accomplish surveys either in-house or by contract. When this occurs, the resulting surveys are almost always single purpose and do not contribute to the national network, even though they may meet accuracy, density, and coverage standards. The

following examples show how horizontal control is used in Federally supported projects and programs and provide an insight as to the importance of accurate and accessible control:

- Planning and construction of large dam projects, such as those conducted by BR, CE, and TVA, which cover several hundered square miles, require many geodetic control stations to delineate the inundated area, to support mapping of the project area, and to provide an accurate reference for construction. The existence of a control network surrounding the area to be inundated reduces the amount of supplemental surveying necessary, allows the use of less costly surveys, and provides a basis for further development projects which will follow.

- Planning, design, and construction of Federal-aid highways spanning multiple-State areas are dependent on horizontal control for route planning and layout, as a reference for construction, for topographic mapping of the route, and for acquisition of rights of way. Without an existing network, additional surveys are necessary, and costly self-checking survey methods are required to complete the work.

- Expensive planning and construction programs in urban areas are dependent upon control. As metropolitan areas expand and join, only an accurate control network covering the entire area can provide a common reference for such activities as property and right-of-way acquisition and alignment of roads, subways, and utility locations. In a letter to us, HUD indicated that it was financing activities that resulted in surveys of questionable accuracy and usefulness and that it needed high-quality control in each of the metropolitan areas. We estimate HUD expenditures for these surveys to be $1.5 million per year.

- Geodetic and geophysical data to determine land stability are needed in planning and site location of nuclear power

plants. The site of a multimillion dollar plant planned for construction in northern California, for example,was disapproved by AEC on grounds of being unstable and thus unsafe as determined by precise horizontal and vertical control and geophysical data. Sites of other nuclear power plants have been rejected on similar grounds (e.g., Hudson River area in N.Y.).

- The Department of Defense requires accurate geodetic positions, in some cases as accurate as one part in a million, for developing, testing, and evaluating Defense weapon systems, such as ICBM and ABM, and for calibrating inertial navigation systems.

A network structured to meet collective needs for control, both present and future, is an efficient and effective means of satisfying Federal requirements. Sufficient evidence exists to support the contention that surveys of minimum accuracy, which satisfy only immediate single-purpose needs, result in an overall higher cost to the Federal Government. We conclude that there is a requirement for a consistent nationwide horizontal control system. This system should include the following:

- A basic network throughout the country to provide control for the special needs of Defense, for scientific studies such as crustal movement, and an accurate primary framework for many lower-order surveys. Since systematic errors inherent in all surveys accumulate with distance, superior accuracy (1:100,000 to 1:1,000,000 is needed in the primary framework so that general-purpose control tied to it will not contain intolerable errors.

- Dense coverage in urban areas to provide control for surveys of property, utilities, transportation facilities, and the like. Stations should be spaced at 2- to 4-mile intervals at an accuracy of 1 part in 100,000.

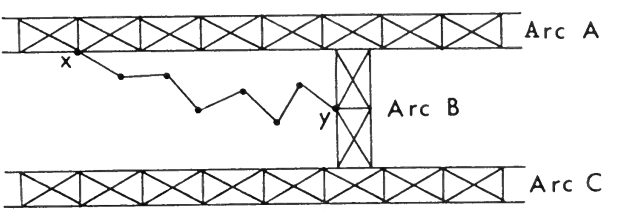
- o General area coverage for use in major Federal programs and for general use by State and local governments and the public accomplished consistent with Federal priorities. Stations should be spaced according to area needs at an accuracy of 1 part in 50,000.

We recommend the building of a nationwide horizontal control system as described above. Resources to carry out control densification in urban areas should be transferred from those funds (estimated $1.5 million annually) which are now expended by HUD clients for control surveys of unknown quality and reusability.

North American Datum.--Before the 125,000 monumented control points comprising the National Horizontal Network can be assigned definitive geodetic positions, they must be interrelated by computations and adjustments to fit a mathematical model of the earth known as a datum. The last overall adjustment of the North American Datum was accomplished between 1927 and 1932. Due to inherent weaknesses in the data used (lack of precise measurements and insufficient astronomic observation) and adjustment procedures (manual computational methods), errors exist in today's network. As a result, extensive resurveys and costly, inefficient piecemeal adjustments are required because new surveys will not fit the existing network in many areas of the country.

The problems of inefficiency and higher costs caused by network errors can be demonstrated by the following examples.

In 1969, GS conducted a second-order survey to fulfill Federal network requirements and to support a topographic mapping project. The survey included a traverse between two first-order arcs of national network control, as schematically shown:



The traverse began at point x and ended at point y. GS should have been able to assume that points x and y on the triangulation arcs were accurate relative to each other, but the published position of y relative to x differed from that determined by the traverse. To check its own work, GS reobserved the traverse and, finding no errors, reported the problem to NOS. NOS determined after considerable data manipulation that distortion had been forced into the arc containing point y to make it fit into the 1927 adjustment. Therefore, because of errors in the network:

- Cost of fieldwork was nearly doubled.
- NOS was forced to expend time and manpower comparing the new survey against old data.
- The new traverse and other new work could not be added to the national net without a piecemeal adjustment.
- All users were forced to accept preliminary positions and maintain separate files.

In the testing and operations of Defense weapons systems, particularly ICBM's, DOD determined that unacceptable errors of unknown magnitude existed within the horizontal network. Because of this, each of the large DOD test ranges has been resurveyed. In one case, DOD performed a highly accurate survey costing $430,000 in the area from Santa Barbara to a point near San Francisco to relate missile launch points at Vandenburg AFB to tracking radars along the West Coast. The survey revealed discrepancies between the new work and the published network coordinates. It was confirmed, as suspected, that the major source of error in the published coordinates was the 1927 adjustment.

Heavy Federal expenditures for surveying are also made in many metropolitan areas. Because of errors in the network, these new surveys do not fit into the existing network, and therefore additional costly and time-consuming fieldwork and data adjustments are necessary.

For example, 3 years ago NOS established control in the Washington, D.C., area in cooperation with the District of Columbia and neighboring counties in Maryland and Virginia. This new survey would not fit into the surrounding network. A local adjustment taking 3 years to accomplish was needed to retain the accuracy of the new survey and fit it into the 1927 Datum. The inconsistencies between the new survey and the old network caused:

- Additional fieldwork to redo some existing control and extend the new survey to make the new data fit.

- Excessive computational and adjustment expenses (estimated at $140,000).

As the above examples indicate, peicemeal adjustments are generally inefficient and very expensive overall. They cost on the order of $500,000 a year for maintaining the network in its present form and are increasing at a rate of $100,000 a year as more new surveys are accomplished. In addition, delays in providing final positional information to users adds millions of dollars to project costs. For example, the new survey of Monroe County, N.Y., was completed 3 years before the data adjustments were completed, and major survey benefits were thereby delayed because the network could not be used as designed.

From a thorough review of many examples similar to the few discussed above, we have concluded that a complete new adjustment of the Horizontal Control Network is clearly needed and that significant benefits will result as summarized below:

- Virtually all significant distortion in the network will be removed, and the resulting datum will be a more reliable framework within which to control subsequent surveys. Incorporation of new data, therefore, will not require readjustment of large amounts of already published data, and thus adjustments can be made quickly, an adjustment backlog is prevented, and users receive final data within a shorter period of time.

- A byproduct of the new adjustment will be a machine-readable data file, and future new data will be incorporated more economically.

- The duplicative effort of maintaining and disseminating unadjusted field data will not be necessary.

NOS has proposed a new adjustment that will require completion of the precise traverse network (3,100 miles), new arcs of triangulation or traverse (10,000 miles) and new base lines and azimuths at a total cost of about $12 million. The computation process is expected to cost an additional $4 million. The total effort would take 10 years to complete if the NOS schedule is followed.

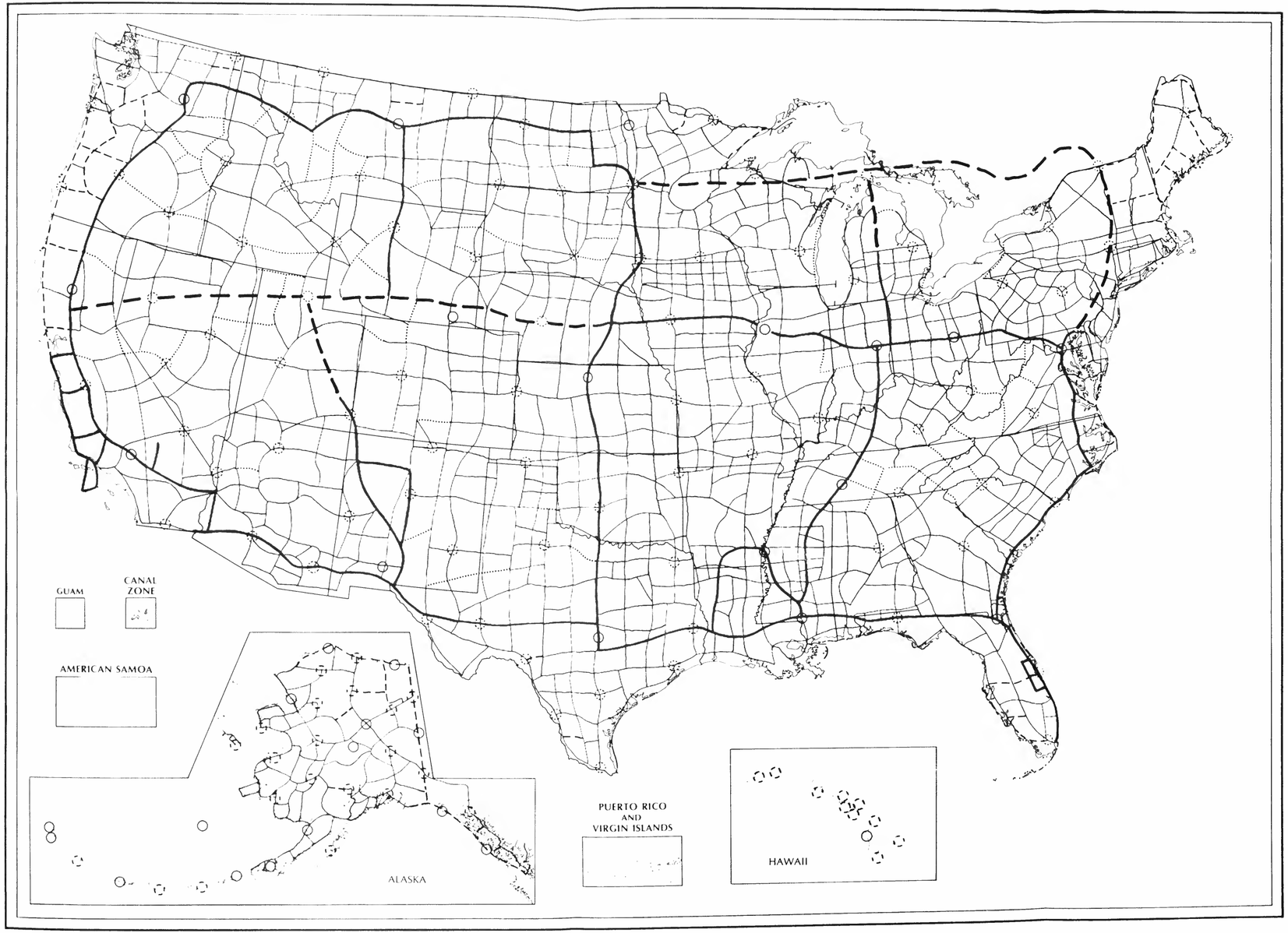
While we believe a new adjustment is necessary, we do not think the NOS proposal is the right way to do it. In view of the substantial benefits, 10 years is too long to wait. As an alternative to the NOS-proposed overall adjustment, large blocks of the network could be adjusted separately by taking advantage of the strength of the transcontinental traverse for the framework and by using the DOD Doppler satellite system to reduce the amount of fieldwork. Thus areas of the network could be adjusted in order of priority, and the basic adjustment of 90 percent of the 48 States could be completed in about 5 years. This procedure (see fig. 5) would require:

- Completion of the transcontinental traverse -- 3,100 miles.

- Lines of conventional traverse or triangulation arcs -- 5,300 miles.

- Doppler geodetic satellite control -- 86 stations.

- Conversion of existing data into a format suitable for computer processing.



NATIONAL GEODETIC PROGRAM

PRIMARY HORIZONTAL CONTROL NETWORK

EXISTING CONTROL

- Transcontinental traverses ... 10,900 miles
- Arcs of triangulation ... 102,600 miles
- Doppler Geodetic Satellite Control ... 32 stations

ADDITIONAL CONTROL NEEDED FOR THE NEW ADJUSTMENT

- Planned transcontinental traverses ... 2,800 miles
- Planned triangulation arcs or lines of traverse ... 5,300 miles
- Planned additional Doppler Geodetic Satellite Control ... 86 stations

CONTROL NEEDED TO COMPLETE THE NETWORK

- Triangulation or traverse ... 11,500 miles
- Doppler Geodetic Satellite Control ... 23 stations

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Figure 5

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Figure 6 shows the savings that can be realized by accomplishing a major part of the new adjustment within 5 years (1974-1979) and completing it within 3 to 5 years thereafter. The 1972 expenditure level ($9.4 million) includes surveys, either accomplished or paid for by Federal agencies, of sufficient size and accuracy to be impacted by a new adjustment of the basic network. The line "expenditures without new adjustment" shows how the cost of the above surveys would increase without an adjustment. It is based on the 1972 dollar, the current work program, and an assumed constant workload. The line "new adjustment level-- post adjustment level" is an extrapolation of the cost of the current workload plus adjustment cost through the period of adjustment and into the 1990 decade. It shows how the program cost declines after benefits from the new adjustment, started in 1974, begin to be realized in 1979. Clearly, by deferring the new adjustment, potential savings are foregone. The savings, however, are contingent upon an increased expenditure level (approximately $1.7 million a year for 5 years -- $8.8 million total) above the present program level to complete a basic adjustment (90 percent of the 48 States). The remaining areas (10 percent) could be integrated into the network within 3 to 5 years thereafter with the addition of 10,500 miles of triangulation and 26 Doppler positions at a cost of $2 million more. If the new adjustment were initiated by the beginning of FY 1974, significant savings would begin by 1979, and the total cost of adjustment would be recovered by 1982.

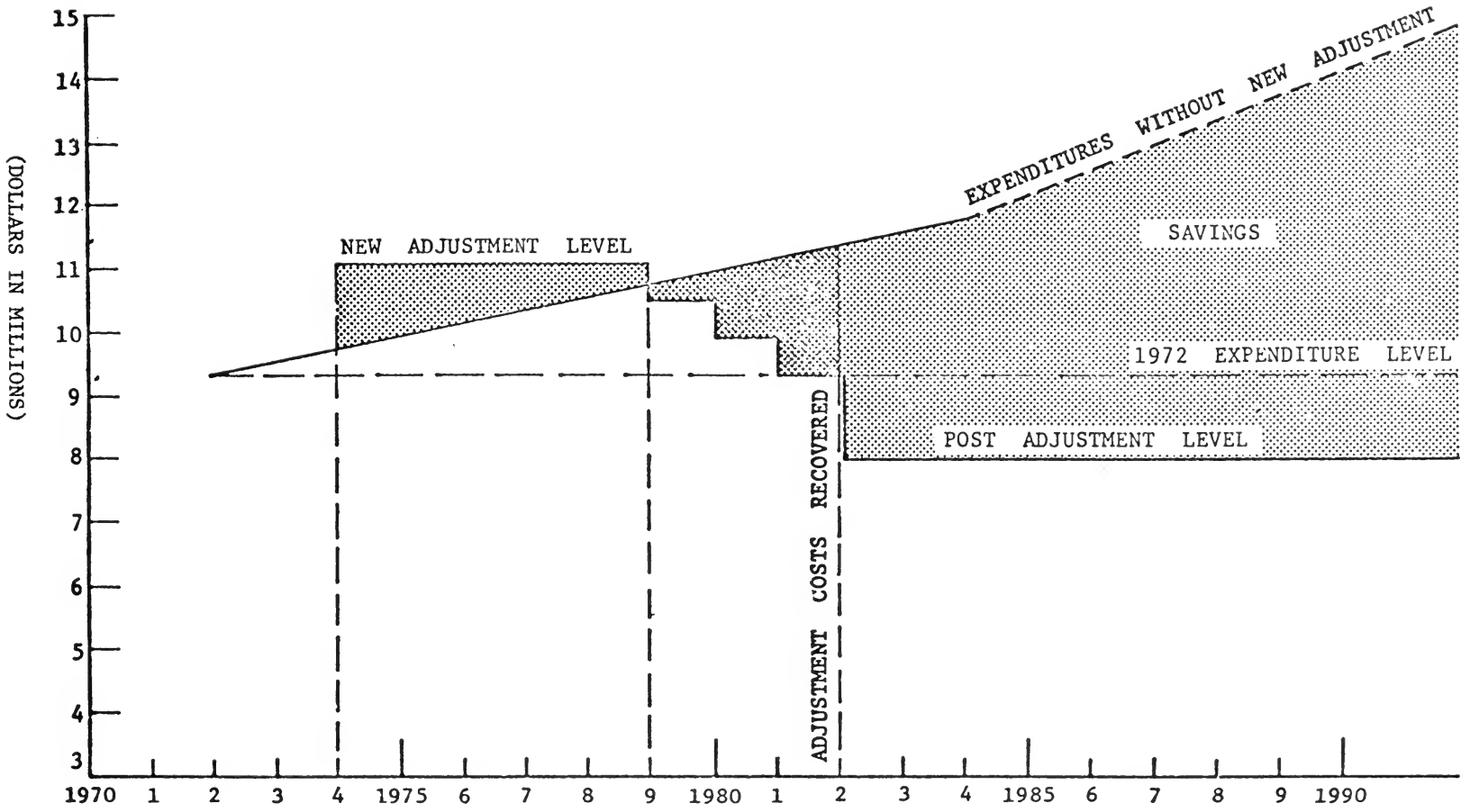
We recommend that the National Horizontal Network be readjusted progressively as described above beginning in FY 1974. We believe $0.4 million of the additional funds can be reprogrammed within the National Geodetic Program; however, an infusion of $1.3 million for the first 2 years will be required. Beginning in 1976, land survey funds from map control and facility surveys can be reprogrammed.

Vertical Control

The fundamental purpose of a nationwide vertical control program is to produce a network of accurate elevations referenced to a common

Figure 6

SAVINGS
from a
NEW ADJUSTMENT OF HORIZONTAL CONTROL



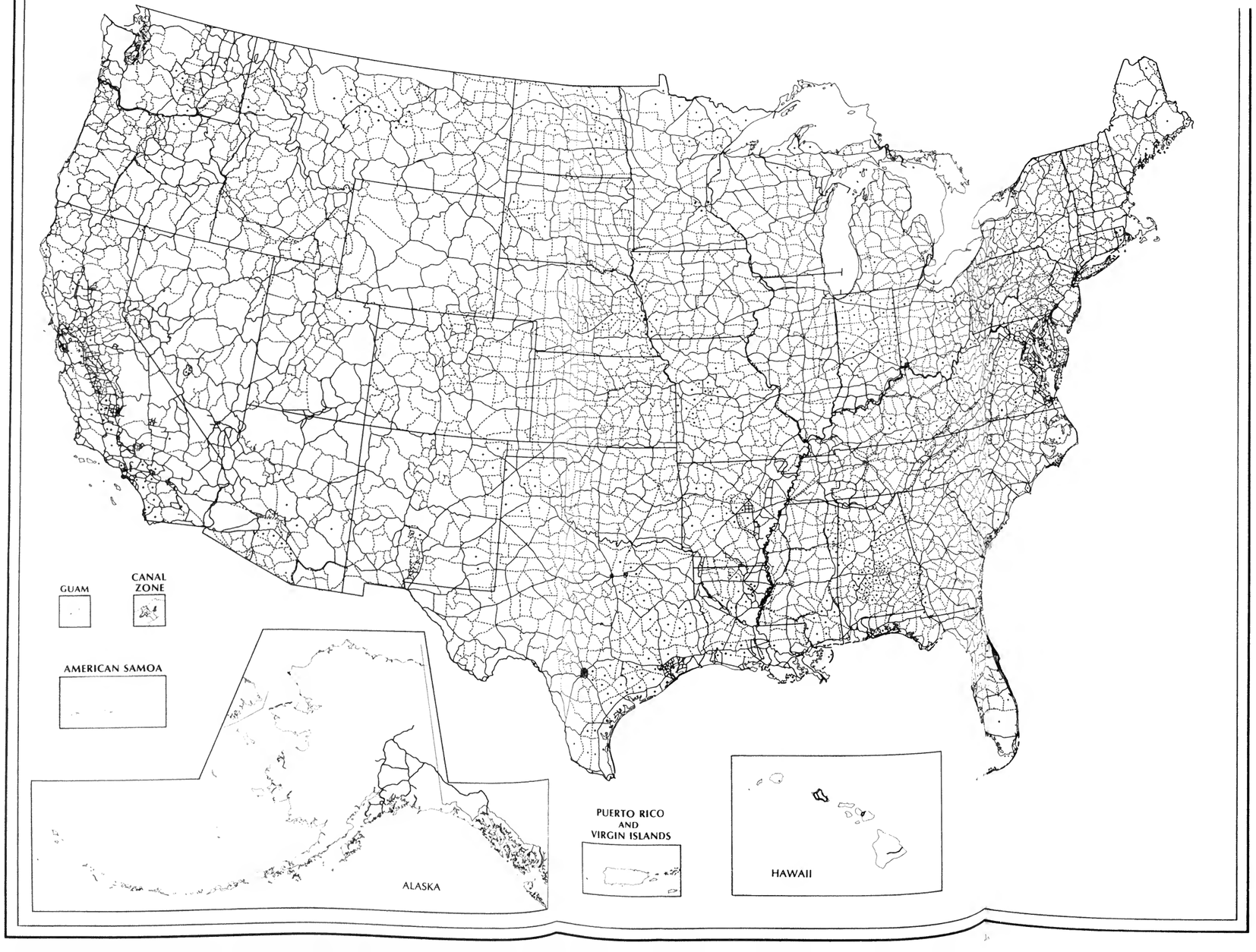
datum (mean sea level). This network consists of interrelated benchmarks forming lines of precisely determined elevation points. Similar to the structural steel building analogy, the basic network thus provides precise vertical control to which less accurate elevation (for either area control or local surveys) can be tied.

The responsibility for the Vertical Control Network (assigned by BOB Circular A-16 rests with NOAA (NOS), with input from several other Federal, State, and local government agencies. Federal organizations, such as GS, DMA, FS, SCS, BR, FHWA, and BPA, contribute to the network as do several State highway departments and some county agencies. The mechanism for submitting requirements for vertical control by Federal agencies as defined in Circular A-16 is essentially the same as that for horizontal control.

The development of the Vertical Control Network was started almost a century ago. First- and second-order level lines (or loops) have been established for the basic network except for a few areas in the Far West (fig. 7). Area leveling has been completed within some of the loops of the basic network, mainly to meet specific project requirements.

Based on the quantity of leveling which has been accomplished, one could conclude that little remains to be done. But only a small percentage of the control established is now usable because of vertical movements of the earth's surface (areas of known movement shown in fig. 8) and the loss of many bench marks (about half of the bench marks established more than 30 years ago are lost). These two factors combine to retard progress in expanding and maintaining the network. Present status is shown in figure 9.

Requirements.--Our requirements review identified many activities conducted by Federal agencies, or by State and local governments with Federal funds, which depend on the availability of accurate vertical control. These requirements, which have been recognized for some time, are generated by activities such as highway and facility design, flood control projects, water management, and the like, as discussed under the section on horizontal control. Also, as found with horizontal control, if vertical control is not



U.S. VERTICAL CONTROL NETWORK

ESTABLISHED LEVEL LINES

— First order

..... Second order

. Additional second order leveling

Note: First- and second-order level lines were established during the last 94 years.

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Figure 7

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available or immediately forthcoming from the national program, agencies tend to survey to meet their own immediate needs, and therefore the work does not contribute to the national network.

In addition, we found evidence of dramatic national problems - - recently the subject of Federal legislation - pertaining to the environment, the use of land and natural resources, and management of the coastal zone which are related directly to vertical movement of the earth's crust (subsidence and uplift). The magnitude of these crustal movements, only recently defined, ranges from less than an inch a year for fault slippage to more than a foot a year where fluids are being taken from underground. Following are examples of problems caused by these movements:

- In San Jose, Calif., railroad tracks are submerged at high tide due to subsidence of 11 feet caused by underground water withdrawal.

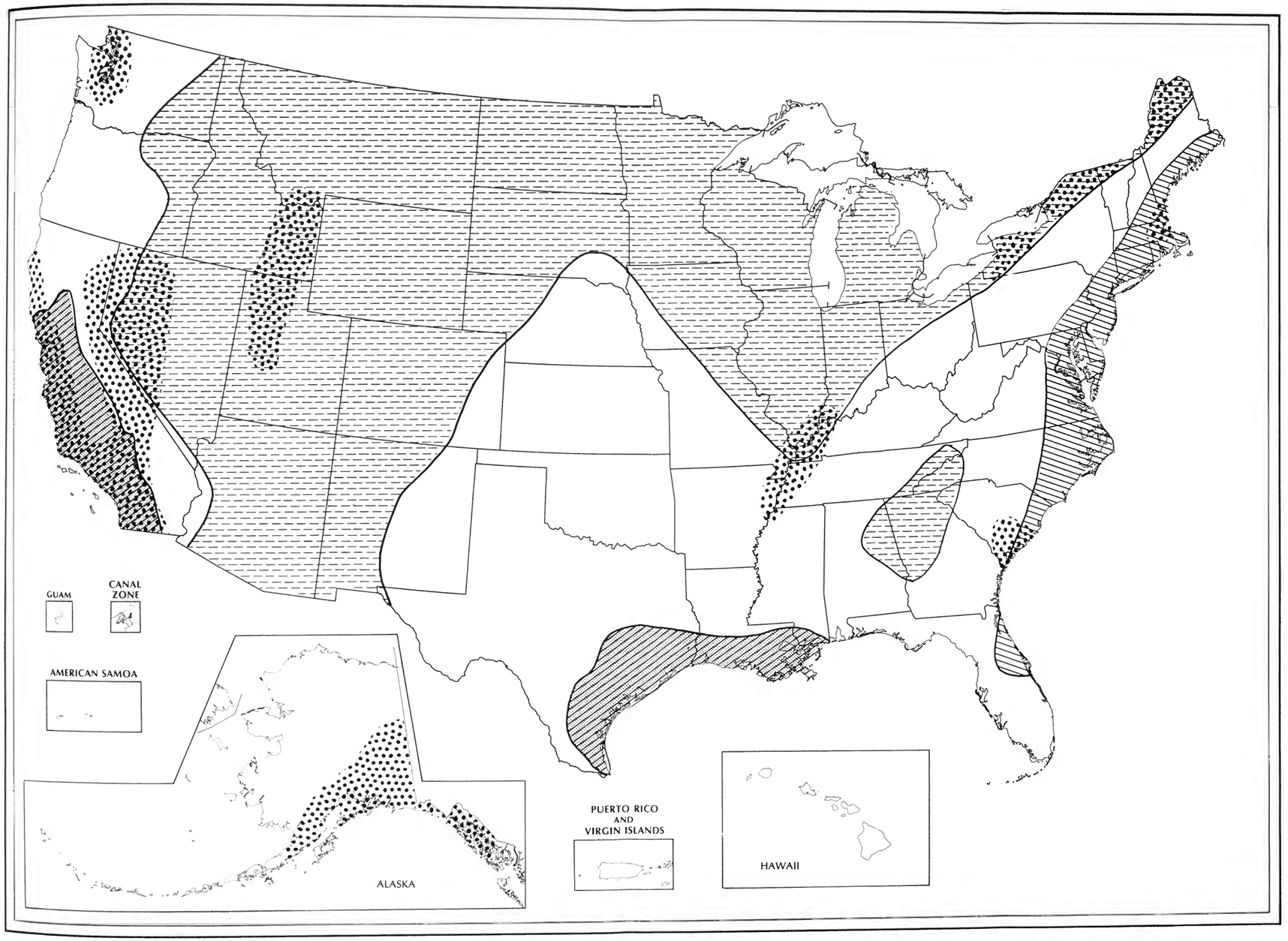
- Subsidence is threatening valuable real estate, altering wildlife habitat, and endangering fresh water supplies of most of the Gulf Coast area.

- Uplift in the Great Lakes area is causing shoreline changes, navigation problems for deep-draft vessels in the north, and floods in the south.

- Tilting of large river basins (upper Mississippi) portends significant navigation and flood-control problems.

Early detection of vertical crustal movement and determining its rate are critical in planning and implementing corrective measures, such as replacing extracted oil with sea water, establishing land-use policies and building codes, building flood-control systems, and providing alternative sources for fresh-water supply (other than underground).

Based on our requirements study, we conclude the vertical control program is falling short of meeting national needs and, therefore, must be expanded and redirected to provide the following:



THE LAND MOVES: VERTICAL CONTROL DETERIORATES

Long-term uplift

Long-term subsidence

Severe subsidence

Seismic activity uplift or subsidence

Note: Vertical crustal movements create engineering, environmental, and legal problems as well as deteriorate the vertical control network.

Figure 8

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- Releveling of the primary lines of the network (at intervals of 100 to 300 miles and on a 10- to 30-year cycle, depending on area needs) to reestablish destroyed bench marks, detect areas of crustal movement, and upgrade accuracy. High accuracy in the primary network is necessary to insure that deterioration occurring in each subsequent survey (at intervals of 25 to 50 miles) does not produce unacceptable errors.

- Releveling and new leveling at high accuracy and close line spacing in areas of known or suspected subsidence or uplift (5 to 10-year cycle, depending on the area).

- Less accurate new leveling for area coverage to meet specific Federal project requirements.

We recommend doubling the national vertical control program. We believe the increase can be accomplished by better coordination of surveys that are now single purpose ($400,000) and by reallocating $800,000 from other Federal land-survey programs.

Related Earth Physics

Our resource data (table 4) shows five agencies spending $7.3 million and 253 man-years in earth-physics activities related to geodesy. These include: observation programs and/or scientific studies concerned with determining the figure of the earth (earth model); locations of polar axis at specific times (polar motion); and programs determining the amount and rate of relative motion of elements of the earth's surface (crustal movement).

An earth model is a worldwide geodetic reference system which represents the size and shape of the earth mathematically, provides a mathematical relationship between independent control networks (datums), and defines the earth's gravity field. The system provides a basic reference whereby:

U.S. VERTICAL CONTROL NETWORK

ADEQUATE LEVEL LINES

Note: These leveling lines are considered adequate based on knowledge of crustal movement and on the probability that bench marks are undisturbed.

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Figure 9

- Worldwide navigation systems can be related to each other.
- Satellite tracking facilities can be connected.
- Launch-to-target relationships can be established to support Defense weapon systems.
- Satellite orbits and missile trajectories can be predicted for both scientific and Defense purposes.
- The relative positions of continents can be established for measurement and study of continental drift.

DOD, NASA, SAO, and NOS are all involved in programs whose objectives are to define accurately the model of the earth. For the most part, these activities are being conducted as part of the National Geodetic Satellite Program (NGSP) which began in 1964. The NGSP was a totally unclassified program with the results being made available to qualified scientists interested in using the data and publishing results. DOD, however, went further and conducted classified activities outside the NGSP for meeting unique Defense needs, including Doppler tracking of the satellite vehicles and positioning of test range trackers.

Overall policy direction was provided by a Geodetic Satellite Policy Board with representation from NASA and the Departments of Defense and Commerce. The policy board was not effective in eliminating duplication since all of the participating agencies approached the problem in different ways using their own observational systems and techniques developed before the board was established.

The observation portion of the NGSP has now been completed, and the data-reduction phase is essentially finished, although NASA is funding an independent professional society, the American Geophysical Union, to prepare an interpretative document summarizing the significant results.

Programs are underway, however, for further improvement of the earth gravity model. NASA and SAO are using existing data to support scientific studies pertaining to the gravity field and its relationship to motion in the earth's crust.

Although no major data-acquisition program is now underway for earth-model development, about 5 years ago at least six competitive and duplicative geodetic satellite observational systems were in operation. These redundant activities no longer exist, but the previous deployment of operational systems vividly illustrates how duplicative efforts can be initiated and continued in the absence of a national-level review.

Polar motion is the variation of the earth's axis of rotation with respect to its physical surface (i.e., the motion of the earth's polar axis within the body of the earth). Since geodetic astronomic observations are taken at different times and must be interrelated, polar-motion information is required to reduce these observations to a common reference system. The relationship between motion of the polar axis and mass shifts in the earth's crust associated with major earthquakes has caused increased interest in polar-motion observations. These observations may provide essential information for earthquake prediction and risk calculations.

Traditionally, motion of the polar axis has been determined by observations of the changes in latitude at a number of observatories around the earth. NOS participates by providing observations from two observatories, at Gaithersburg, Md., and Ukiah, Calif. (there are five worldwide). NASA and SAO have recently engaged in independent investigations of polar motion using observations on earth satellites, laser ranging to the moon, and radio telescopes. DOD has been able to compute variations in polar-axis positions using observations on Doppler satellites as a byproduct of its Doppler tracking network. The NASA and DOD techniques are still in the development stage.

We believe that the two NOS observatories provide essential input to a worthwhile program and should continue to operate until their observational techniques can be replaced by new technology. Development of an improved system is considered to be a valid objective and should continue. Before any new operational effort is mounted, however, an extensive overall review should be conducted and a single system selected.

Crustal movements (horizontal and vertical displacement of one portion of the earth's outer surface with respect to another) are exhibited in many ways. In some cases the movement may be so slight as to be undetectable for several years, in other cases the change is dramatic. Numerous surveys to measure horizontal and vertical movements have been undertaken in areas where known or suspected seismic activities could endanger the economy of a region or its inhabitants. For several years NOAA and GS have periodically made precise measurements along and across the San Andreas fault of California. Both agencies are translating crustal-movement data into environmental effects and prediction of seismic events. Additionally, NASA, NOAA, and SAO are investigating ways to determine measurements by using laser ranging and radio telescopes with the objective of detecting changes (crustal movement) over both short and long distances.

We believe crustal-movement surveys are required to maintain a viable geodetic network and should continue as part of the National Geodetic Program. Even though accurate measurements to detect crustal movements over both short and long time periods are necessary to support studies related to earthquake risk and prediction, the responsibility for providing these measurements should reside with the National Geodetic Program manager.

We recommend that the National Geodetic Program manager be given responsibility to (1) coordinate all Federal civil earth-model development activities that contribute to the National Geodetic Networks and (2) accomplish geodetic measurements -- that is, positions, elevations, distances, and changes in distance -- to support polar-motion and crustal-movement investigations or studies.

GEOPHYSICAL PROGRAMS

Federal geophysical programs include gravimetric, magnetic, and seismic surveys. This section discusses only those programs pertaining to the land, since marine geophysics is treated in the section on Marine Mapping, Charting, and Related Surveys. Geophysical programs are conducted by seven Federal agencies to meet a variety of needs, including assessment and location of resources, adjustment of geodetic measurements, support of navigation systems, and support of DOD weapon systems. FY 1972 expenditures were $3.3 million and 142 man-years (table 4).

Gravity

Knowledge of the intensity and direction of the earth's surface gravity is essential for analyzing subsurface structures (location of ground water, mineral resources, other geologic features); calibrating inertial guidance systems; accurately computing missile trajectories; and adjusting and orienting geodetic networks.

NOAA collects gravity data and operates a national land gravity data bank of approximately 300,000 points to meet geodetic and scientific needs. The general objective for gravity-data coverage of the U.S. is one station per 30 to 40 square miles (about 70% complete). GS performs gravity surveys for specific projects such as ground water, mineral resources, and regional geologic investigations, and the data are usually collected at closely spaced points over small areas. DOD collects data, where coverage is not available from other sources, particularly in the vicinity of ICBM launch sites. A significant amount of gravity data is collected by non-Federal organizations, primarily oil companies, for use in locating natural resources.

DMA maintains a worldwide gravity data bank on both classified and unclassified data. DOD unclassified data of the U.S. have been turned over to NOAA for servicing other Federal agencies and the public.

We have concluded the following:

- There is a need for gravity data for orientation of the geodetic control network and DOD weapons systems as well as for locating natural resources.

- There is no detectable overlap in data collection programs.

- Although the DOD unclassified data have been turned over to NOAA, fewer gravity surveys would be needed if additional classified data held by DOD and proprietary data held by various Federal and private organizations were released.

We recommend that DOD review its classification policy with the objective of releasing more gravity data to the civilian community, and that civilian agencies make greater use of classified gravity data by working through DOD channels and by direct negotiations with the owners of proprietary data.

Magnetism

Magnetic data are being acquired to support efforts to understand and predict changes in the earth's magnetic field. The data are also needed for mineral resource studies, geologic investigations, geophysical studies of the earth's crust and interior, and navigation.

As part of its Earth Science Program, NOAA/ERL operates observatories to determine annual and secular changes in the earth's magnetic field. Data are provided to NOAA/EDS for dissemination to users. GS and TVA collect magnetic data for use in geologic investigations and resource studies. NASA is collecting data by use of satellites in order to describe the earth's magnetic field.

We believe there is a continuing need to collect magnetic data and improve the knowledge of the earth's field. We detect no overlap in the collection of these data and recommend no change in the level of this activity.

Seismology

Seismic data are collected for analysis and investigation of geologic structures and earthquakes and are essential for predicting a tsunami.

NOAA/ERL operates a network of seismological observatories and collects data from some 400 cooperating stations around the world. GS collects data from a system of some 150 remote seismographs (about half in California) as part of its earthquake investigation program.

AEC operates seismometers which collect information to evaluate the impact of atomic tests and to study the stability of proposed sites for atomic facilities.

Seismic data are only incidentally related to MC&G. Although the data are sometimes published on a map or chart, the requirements for data collection and analysis are based on the needs of scientific investigators.

A combination of GS and NOAA efforts in seismology could result in an overall improvement in the use of equipment and data. Such a consolidation, however, should be considered in terms of the geologic or earthquake programs, not MC&G.

CADASTRAL SURVEYS

Program Descriptions

Today, Federal agencies administer more than 1 million square miles of public lands -- about one-third of the total U.S. land area. Cadastral surveys, as used in the context of this report, are performed to establish or reestablish positions that define the boundaries of divisions or subdivisions of Federal lands. The positions are usually marked on the ground with monuments, and the surveys are recorded in the form of official field notes and plats. These documents are distributed by the agency performing the survey and are heavily used by Federal, State, and local organizations which own, manage, transfer, or tax lands.

As shown in table 4, 10 agencies spent $14.1 million and employed 790 people for cadastral surveys in FY 1972. The Bureau of Land Management ($8.6 million) and the Corps of Engineers ($2.9 million) had the largest programs.

The rectangular system of cadastral surveys was started in 1785 and has been extended over more than 2 million square miles outside the area of the Thirteen Original Colonies. The Nation needed a reference system that could be established quickly for legally describing and transferring public lands, and rectangular subdivision was selected as the most expedient system. Only relative local accuracy was considered important, and therefore the public-land surveys were not tied to a geodetic reference system. Consequently, cadastral surveys are of minimal value to the geodetic surveying community, and positions and areas based on the cadastral network are not directly relatable to the geodetic network.

The major activity in the lower 48 States is revision of surveys accomplished prior to 1910. Revision surveys, which consist primarily of searching for and reestablishing original land corners, provide boundary information needed for managing Federal lands. For search and recovery of existing boundaries,

precise survey skills are less important than familiarity with the local history, vegetation, and geology. Revision surveys, therefore, can be handled most effectively by local units of the appropriate land-management agencies and should not be a function of a central MC&G agency. However, revision surveys too large or complex for the local capability of a land-management agency should be referred to and accomplished by a national survey agency.

Requirements

The Federal Government has requirements for cadastral surveys in support of:

- Management of Federal lands. Federal lands adjoining non-Federal lands cannot be managed for maximum output unless the boundaries are clearly and permanently established, for example:

  Intermingled lands.--Some of the Federal lands are intermingled with private and State lands, and, since boundaries are not accurately defined, significant acreage is contested. Although the Government consolidates ownership by land exchange, most areas will remain intermingled indefinitely. The investment in cadastral surveys to resolve contested boundaries produces tangible benefits which far exceed the cost of the surveys. For example, in Oregon alone, approximately $25 million a year could be produced in revenues from timber and mineral sales if ownership boundaries were clearly defined -- with an outlay of $6 million for cadastral surveys.

  Different land management policies.--Federal lands are managed by different agencies under different legislative mandates. The boundaries must be established in order to exercise these mandates fully.

- Disposal of Federally owned lands. Lands classified for disposal are required by statute to be surveyed. Most of the lands being disposed of are in Alaska (discussed later in detail).

- Land resource management information systems. Federal agencies have a relatively new requirement for cadastral data as an element of land resource management information. Many sophisticated mathematical modeling systems are being developed which integrate the location and characteristics of land elements such as soil, slope, vegetation, and ownership, simulate defined input actions such as road construction or timber cutting, and then indicate the impacts of such actions. These systems can be extremely valuable in providing Federal managers with a wide array of definitive choices prior to making a specific land-use decision.

Cadastral vs. Geodetic Reference

The independent nature of the cadastral reference system stymies efforts to develop management information systems. Traditionally, many earth-resource inventories as well as legal land descriptions have been based on the cadastral system. Reference of this system to plane surfaces of the earth rather than to a geodetic surface has not caused serious problems at the purely local level. But Federal lands, and resources on and beneath these lands, must now be managed for their regional and national as well as local impacts and benefits. Regional and national data will be unreliable, and the new computer-assisted planning systems will be ineffective and wasteful unless the various elements of geographic information derived from the cadastral system are properly correlated and referenced to the national geodetic system.

Much of the same ground is being surveyed by different Federal agencies on their preferred reference system. Even though immediate objectives for the surveys are different,

similar equipment, methods, and expertise are applied. These inefficiencies will continue as long as the two major national survey programs are independently managed.

Combined National Basic Cadastral and Geodetic Surveys

There is no Federal requirement to integrate totally the cadastral network and the geodetic network; this would take hundreds of years and would have questionable benefits. A start must be made to tie the basic networks, however, in order to overcome the above problems. We conclude that Federal cadastral surveys can be accomplished most efficiently by redirecting and separating the existing cadastral survey programs into (1) a national basic program and (2) local land management oriented programs. The latter programs should remain the responsibility of the land management agencies. The national program should:

- Perform new cadastral surveys by procedures which will tie public lands to the geodetic reference system so that information can be correlated to either system.

- Define and establish a network of geodetic points within the existing cadastral system so that public lands can be referenced to the geodetic system.

- Provide standards and procedures to which land-management agencies must adhere in performing local cadastral surveys. These would be minimum standards for all States but would be overridden in States with more stringent local standards.

In light of their potential interrelationships and the opportunities for greater efficiency, we conclude that basic cadastral surveys and geodetic surveys should be conducted under single management. Opportunities for integrating these surveys must be treated on a project by project basis. This is nearly impossible to achieve across agency and departmental lines. Also, it is difficult for any single land-management agency to be objective in programing work to meet both in-house and national requirements.

We therefore recommend transferring appropriate cadastral surveying functions of BLM (excluding corner search and boundary marking) to a new central MC&G agency. The new agency would have responsibility for defining and implementing a national cadastral survey program with flexibility to respond to requests for local surveys of national significance.

Cadastral Surveys in Alaska -- A Unique Opportunity to Do the Job Right

We examined the current Alaska cadastral survey program in depth and found requirements, the size of the job, and cost and time estimates as follows:

Requirement	Area (Square Miles)	Estimated Cost ($ Millions)	Target Completion Date
Native claims boundaries	63,000	$ 90	1995
Public land boundaries	125,000	*	*
State selection boundaries	163,000	33	2045
Mining claims & other surveys	39,000	Negligible	Continuing
	390,000	$123	

* High-priority boundaries will be surveyed in conjunction with State selection and native claims; additional surveys will be minimal for the next 20 years.

Except for the mining claims and other surveys, survey requirements were generated by recent legislation, specifically the Alaska Statehood Act and the Native Claims Settlement Act.

Only 3 percent of the required cadastral surveys in Alaska are completed, and much of the geodetic work remains to be done. There is, therefore, a unique opportunity to attack these surveys with an integrated program. Analysis of the Alaska survey requirements

indicates that integration of the two survey efforts should start with the State Selection Program.

The State selection parcels are large blocks (hundreds of square miles in area, see fig. 10) and lend themselves to a synoptic geodetic approach. The 70-year time frame and $33 million cost are not consistent, however, with the legislation requiring Alaska to select and patent lands within 25 years. Also, the $33 million doubtlessly will be inflated over that extended period. Tripling the annual expenditures for this activity to meet state requirements is not a reasonable solution. Alternative actions can be taken which we believe will meet the objectives of all parties at less cost and in less time:

- Reexamine the Federal role. BLM has traditionally subdivided all 36-square-mile rectangular townships into 1-mile square sections. But, there is no longer Federal need for internal surveys of these townships. Interpretations of recent legislation relax requirements for boundary monumentation to a 2-mile spacing around the perimeter of state selected lands.

- Apply modern technology to a greater extent by using Doppler technology for positioning.

In at least one case, BLM and Alaska have jointly agreed to relax the requirement for monumenting township boundaries to expedite transfer of land to the State. For State selected lands between the Naval Petroleum Reserve and the Arctic Wildlife Refuge, near Prudhoe Bay, only designated township corners were established. When the theoretical position of a corner was within a reasonable distance of a geodetic control station, the corner was not set but simply referenced from the control station. It then became Alaska's responsibility to run in additional corners and mark boundaries, as needed.

If this approach were used for all the State selected lands (with appropriate application of new technology), the State's subdivision surveys would cost no more and very likely less.

Assuming that second or higher order geodetic control were available at a density of about one station for every four townships (12-mile interval), a section survey from a control station would vary from 5 to 25 miles, slightly less than is normally required under BLM standards for the rectangular system. The current program and alternatives (Proposals A and B) for surveying the State selection areas are portrayed in figure 11. The advantages and disadvantages for each are summarized below.

Current Program

Advantages

- Federal/State boundaries surveyed.
- Greatest number of monumented points.
- Traditional rectangular pattern of townships with perimeter monumentation at 2-mile spacing.
- Interior monumentation -- corners set around all townships, not just those on the Federal/State boundaries.

Disadvantages

- Excessive cost for unneeded interior monumentation.
- Most costly overall.
- Longest survey time -- 70 yrs.
- Single purpose -- no horizontal geodetic control established.

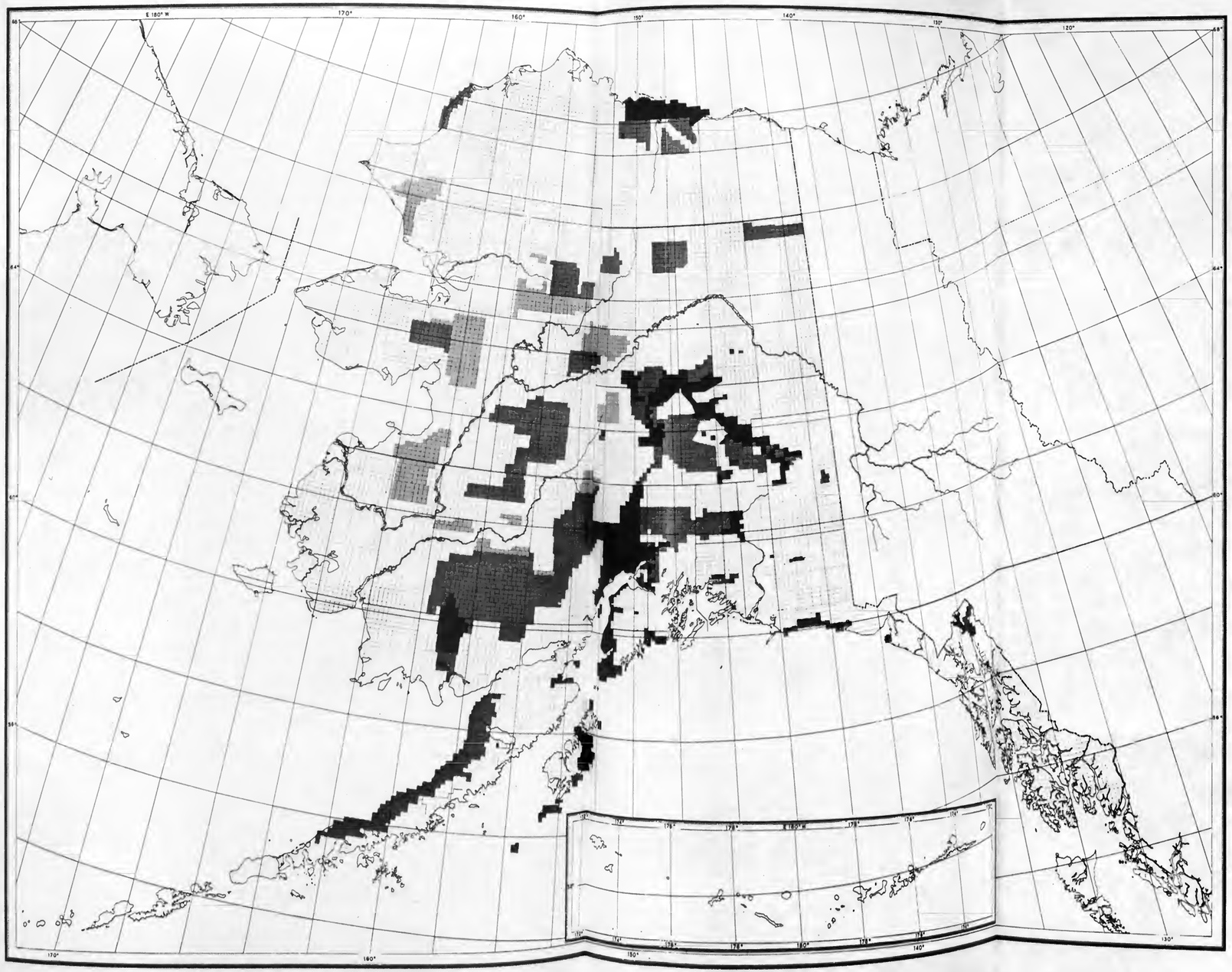
Proposal A

Advantages

- Least costly
- Shortest survey time -- 6 years.
- Multipurpose monumentation -- horizontal geodetic control established.

Disadvantages

- Legislation may have to be rewritten or reinterpreted to overcome need to survey lands totally prior to patenting and eliminate need to survey State selection boundaries.



ALASKA CADASTRAL SURVEYS

STATE LAND SELECTION PROGRAM

Surveys completed

Surveys required

Unsurveyed lands available for state land selection

June 1972

Figure 10

522-986 O - 73 (Face p. 51 blank)

Proposal A (Cont.)

Advantages	Disadvantages
o Increased accuracy of monumentation.	o Federal/State boundary not surveyed -- increases difficulty of Federal land management.

Proposal B

Advantages	Disadvantages
o Less costly than current programs.	o More costly than Proposal A.
	o Longer survey time than Proposal A.
o Less survey time than current program -- 15 years.	o Legislation may have to be rewritten or reinterpreted to eliminate need to survey all lands prior to patenting.
o Multipurpose monumentation,	
o Federal/State boundaries surveyed.	o Fewer monuments than current program.
o Increased accuracy of monumentation.	
o Satisfies horizontal geodetic control requirements.	
o Less time required than current program for subsequent subdivision surveys.	

Proposal A is the least costly and can be accomplished in the shortest time. It, however, neither meets statutory requirements for performing boundary surveys prior to patenting the lands to Alaska, nor establishes perimeter boundaries of the lands remaining under Federal ownership.

Proposal B, the integrated geodetic/cadastral program, is the most advantageous to all parties in the long run even though no immediate savings to the Federal Government will ensue. Current costs will remain about level ($570,000 annually), but since time required for surveying will be reduced from 70 to 15 years, we estimate total costs will be reduced from $33 to $9 million. Reinterpretation of legislation may be necessary, however, to circumvent the requirement for 2-mile perimeter monumentation of all townships.

Some savings can also be realized in the native claims program (fig. 12). They will not be proportional to those in the State selection program, however, because:

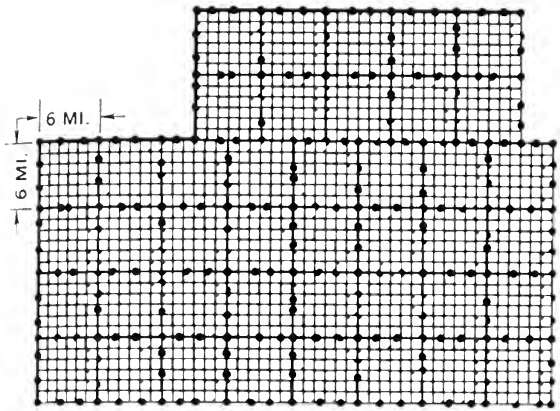
- Most of the parcels are small and isolated, and the surveys are difficult to program and efficiently perform by the integrated approach.

- Perimeter monumentation of interior townships, which offers a significant opportunity for savings in the State program, is not a requirement for the native program.

Savings can be realized on the larger native claim parcels by integrating the surveys and making greater use of modern methods such as Doppler satellite technology. We estimate these savings to be as much as $5 million over the period of the program ($0.25 million annually).

We recommend implementation at the earliest possible date of a combined geodetic/cadastral program (Proposal B) in Alaska to meet requirements for State selection boundaries and for other cadastral surveys in Alaska, as practicable, and to provide geodetic control for multipurpose use.

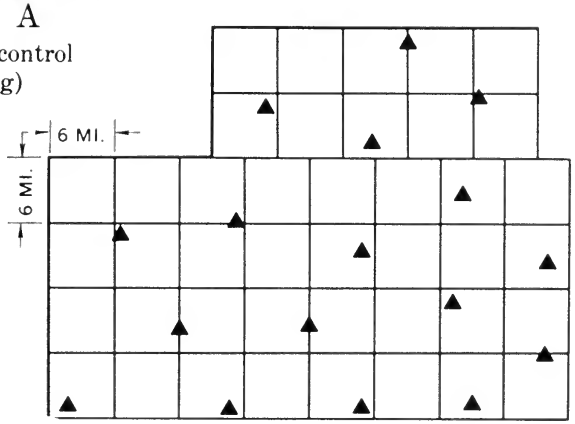
ALASKA CADASTRAL SURVEYS
WAYS TO SAVE TIME and MONEY
in the
STATE LAND SELECTION PROGRAM
CURRENT PROGRAM



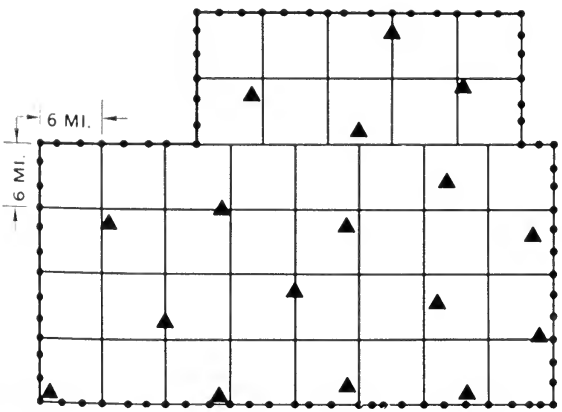
Monumentation (•):	2-Mile interval along township lines
Accuracy:	1:1,000
No. of Points:	28,000
Cost:	$33.2 Million
Time:	70 Years
Cost/Year:	$470 K
Horizontal Geodetic Control:	NOT SATISFIED

PROPOSAL A
(Establish geodetic control at wider spacing)

Monumentation (▲):	12-Mile interval
Accuracy:	1:20,000
No. of Points:	1,500
Cost:	$3.0 Million
Time:	6 Years
Cost/Year:	$500 K
Horizontal Geodetic Control:	SATISFIED

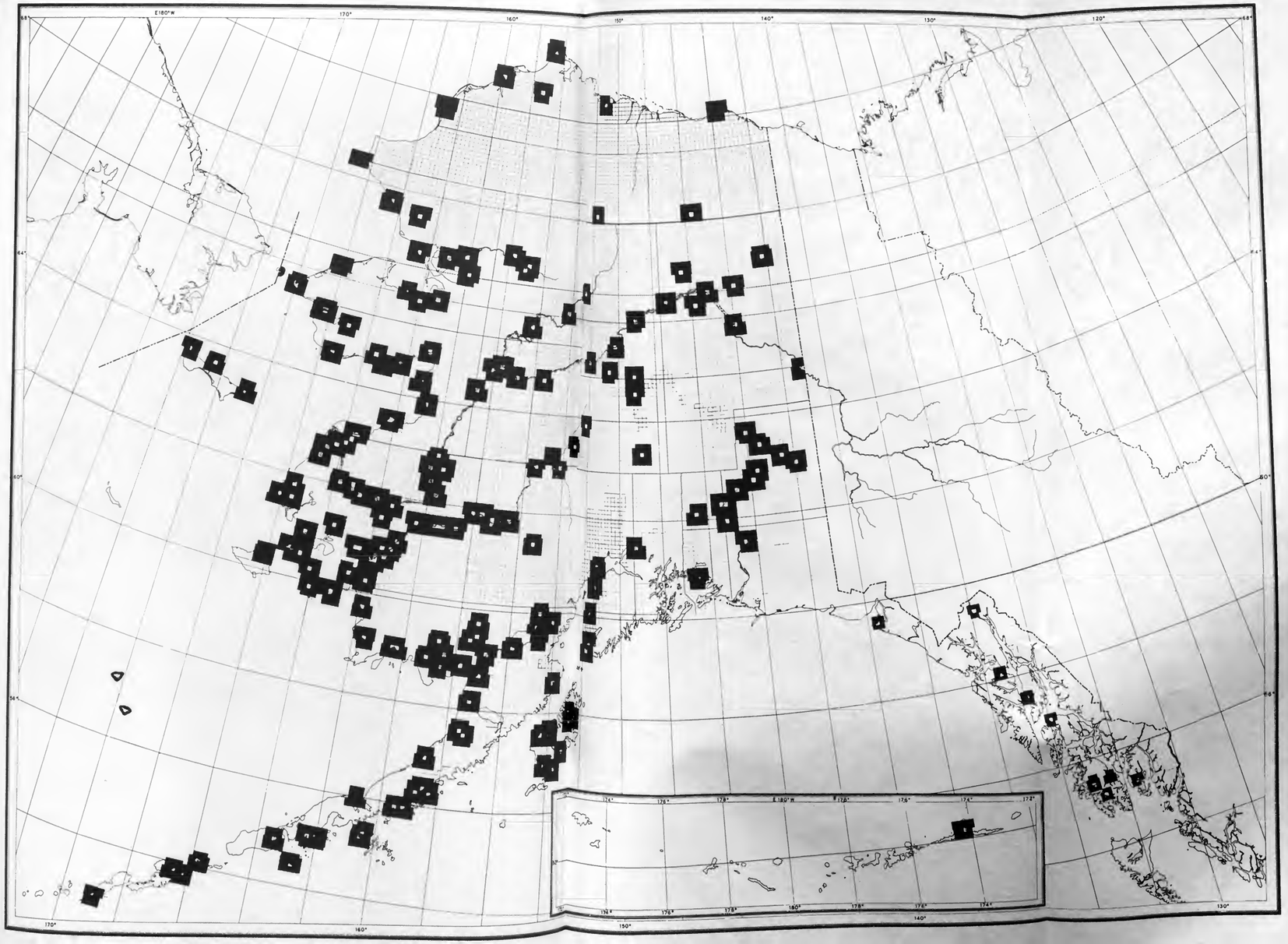


PROPOSAL B
(Same as proposal A plus 2-mile spacing of stations along boundaries)



Monumentation (▲):	12-Mile interval in interior
(•):	2-Mile interval along boundary
Accuracy:	1:20,000-Interior
:	1:1,000-Boundary
No. of Points:	7,500
Cost:	$8.5 Million
Time:	15 Years
Cost/Year:	$570 K
Horizontal Geodetic Control:	SATISFIED

Figure 11



ALASKA CADASTRAL SURVEYS

NATIVE LAND SELECTION PROGRAM

Surveys required

Figure 12

June 1972

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FACILITY SURVEYS AND MAPPING CONTROL

Facility Surveys

Facility surveys provide positional information supporting design, construction, and operation of transportation facilities, utility and water control systems, other public works projects, and military installations and systems. These surveys are generally local in extent, closely integrated with both design and construction, and essential to the economic and timely performance of the agencies' primary engineering missions.

Table 4 shows that 17 Federal agencies spent $30.2 million and 2,072 man-years on facility surveys meeting at least one of the following criteria:

- o Modern equipment capable of accurate surveys was used.
- o The survey covered an area of at least 10 square miles.
- o The survey extended at least 5 linear miles.

There are many additional surveys of lesser accuracy and extent being conducted by Federal agencies for which resource data were not requested for our review. These are very local, almost always are completely integral to the activity they support, seldom, if ever, remain after the project is completed, are not likely repeated, and do not need to be related to a national reference system. In our opinion, control data established by such surveys, while critical to the activity they support, offer little, if any, potential for further use for another project. Therefore, these small surveys are considered no further.

Many of the surveys which met our criteria also offer little potential for further use, although some of them do. We found a number of them were only small subsidiary services to large engineering activities. For example, surveys for the construction and maintenance of Forest Service roads meeting our reporting criteria cost that agency about $6 million annually, while road

construction costs more than $200 million. Each Federal land management agency conducts public works programs, or the like, and has management responsibility over survey activities to support its programs. Funds to finance these surveys are justified and appropriated as part of the primary mission activity.

Mapping Control

Mapping control provides a framework of horizontal positions and elevations for the accurate depiction and placement of features on a map. The control is routinely established through ground surveys (fieldwork), and photogrammetric triangulation (office). As shown in table 4, seven agencies spent $10.7 million and 524 man-years in FY 1972 on field surveys for establishing and photo-identifying control points in support of mapping. Aerotriangulation expenditures are included in table 5 (Land Mapping and Charting) on page 63 and table 7 (Marine Mapping and Charting) on page 111.

The amount of field vs. office work varies substantially from agency to agency and even from project to project within an agency. The accuracy and density of field control points needed in compiling a product depend on the accuracy desired in the product as well as on the degree to which aerotriangulation is used. Generally speaking, map control requirements can be met if horizontal positions are known to $\pm$10 feet and elevations are known to one-third the contour interval (6 ft. for a 20-ft. contour interval). Also, since almost all of today's original mapmaking is based on photography, the need for field control to be identifiable or related to identifiable points on photography is much more important to mapping than is permanent monumentation.

The Topographic Division, GS, spent $5.9 million of the above total in FY 1972 for horizontal and vertical control surveys and for photo-identification of control points in support of the National Topographic Program. In large areas where required National Network control is not available prior to the mapping project, the Topographic Division performs second-order geodetic surveys using specifications and standards approved by NOAA. This geodetic control, which costs GS $476,000 annually, is included in the National Network. The NOS field survey effort in support of

charting is primarily devoted to the photoidentification of existing control for nautical and aeronautical charting, although some geodetic surveys are accomplished where adequate control is not available. Other agencies, including FS, CE, and TVA, establish mapping control by means of field surveys in much the same manner as does the Topographic Division. Their efforts, however, are more restricted in terms of the size of areas surveyed because their mapping projects are generally local.

Opportunities for Savings

The increased use of aerotriangulation procedures in conjunction with aircraft photography has significantly reduced the amount of field surveys required for mapping, as evidenced by a 22 percent decline in the number of GS field control parties over a period of 5 years. Recent technological advances in aerotriangulation methodology make possible additional reduction in supporting field surveys -- particularly for horizontal control.

By making use of these technological advances, we believe the civilian agencies can reduce the need for horizontal control surveys for mapping. This reduction could be as much as $2.5 million annually. Realization of these savings, however, is predicated on expenditures for capital investments in equipment and personnel training, as described in the photogrammetry section of Technical Services.

We recommend that immediate steps be taken to develop a civilian capability (initially within GS) to exploit fully advanced aerotriangulation techniques.

Since there are several agencies involved in cadastral, facility, and mapping surveys, many of which are interested in the same areas of the country, the probability of more than one survey being conducted over the same area is high. We recognize that upgrading these surveys for multipurpose use would generally require additional effort with a potential resultant delay in the project being supported. There are instances, however, where some additional

effort on the part of the agency originally surveying an area could alleviate the need for resurvey and thus reduce overall costs to the Government. For example, vertical control surveys for larger water control projects, if documented and made available, could provide usable vertical control for mapping. Likewise, if vertical control accomplished for mapping were distributed widely, many surveys for other purposes might not be necessary. Duplication of horizontal control surveys could also be reduced, although the cost of documentation and upgrading a horizontal survey to meet multipurpose needs may be more expensive than that of a vertical survey. We are not in a position to say which surveys should be upgraded (and to what extent) and which should not be. Such decisions will need to be made on a case-by-case basis with due consideration being given to the following factors: other existing and potential requirements; existence of control for the area; extent and nature of the survey effort to be undertaken; and the impact on the project which the survey is to support. Although estimating resultant savings is difficult, we expect many of the present survey activities can be curtailed after a few years thereby reducing expenditures by at least $3 million annually (10% of the reported 1972 resources).

We recommend that the new agency be given full responsibility and authority to review and coordinate facility, cadastral, and mapping-control surveys of Federal programs, with the goals of reducing duplication and providing maximum contribution to a control data base for use by all sectors. Recommended criteria are:

- *Linear surveys of 10 miles or more in length.*
- *Area surveys covering 25 square miles or more.*
- *Surveys costing $10,000 or more.*

After reviewing the requirements of a requested survey and considering overall national and local needs, the new agency should either accomplish the survey itself

or recommend that it be accomplished by the requesting agency (in-house or by contract) by one of the following approaches:

- *With procedures and specifications necessary to meet standards for improvement or extension of the geodetic networks.*

- *By the most expedient means to meet only the immediate needs of the project.*

- *To meet project needs, but with adequate monuments and documents for other uses.*

LAND MAPPING

Maps of the land showing contours, drainage, and cultural detail, and often special management and thematic information, are used heavily by numerous government agencies that manage national development programs. To the extent feasible and economical, the maps produced by Federal agencies should be multipurpose, their existence should be made known, and they should be available to other Federal agencies, State and local governments, and the general public. Ready availability of these maps and the data used to produce them would give substantial assistance in meeting requirements, reducing duplication, and assuring overall efficiency in national efforts dealing with the land and its resources.

In the conduct of our study, we sought answers to the following questions:

- How can national requirements for land mapping and charting be most effectively validated and coordinated?
- To what extent can limited-purpose mapping in support of agency programs be incorporated into the national effort?
- Are there significant unmet national requirements for land mapping?
- What are the effects on the national program of cooperative arrangements with State and local governments?
- What advanced techniques can be applied to increase production and responsiveness?

Answers to these questions are contained within the sections below, along with pertinent conclusions and recommendations.

We found 28 agencies spending $96.4 million and employing 5,022 people in domestic land mapping in FY 1972 (table 5). For the purpose of discussion, the effort has been divided into three categories.

- National Topographic Maps -- $36.3 million. These multipurpose base maps prepared primarily by Geological Survey are the most widely used because they provide not only a large amount of fundamental information but also a framework upon which other more specialized maps can be prepared.

- Special Base Maps -- $21.5 million. These maps are prepared by several agencies as bases upon which to display special information related to their missions. Some of them are derived from and are similar to products in the national program -- but none of them are a part of that program.

- Thematic and Other Maps -- $38.6 million. This category includes composites of base maps with thematic or management information and local project maps, usually very large scale, which provide basic terrain data. The base maps for these products may be one of the above or a base independently prepared.

TABLE 5

FEDERAL LAND MAPPING AND CHARTING BY PRODUCT

(FY 1972 Expenditures in Thousands of Dollars.
Resources Shown in () Contracted to Other Agencies.)

	Multi-Purpose								Special Purpose												Aeronautical Charting		Total		Related Activities		
	Topographic Maps		Planimetric Maps		Photos		SubTotal		Geologic Maps		Soil Maps		Project Maps		Cadastral Plats		Other Maps		Subtotal								
	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY	Description
DEPARTMENT OF STATE																											
Agency for International Development	-	-	-	-	93	-	93	-	- (553)	-	- (196)	-	-	-	-	-	-	-	-	(749)	-	-	93	(749) -	-	-	
DEPARTMENT OF DEFENSE																											
Defense Mapping Agency	700	49	10	-	930	81	1,640	130	-	-	-	-	300	18	-	-	-	-	300	18	6,365	288	8,305	436	-	-	
Inter-American Geodetic Survey	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,100	106	2,100	106	-	-	2,100	106	-	-	
Air Weather Service, U.S. Air Force	-	-	-	-	140	39	140	39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	140	39	-	-	
Corps of Engineers, U.S. Army	664	46	119	7	1,006	55	1,789	108	-	-	-	-	2,177	151	54	5	306	24	2,537	180	-	-	4,326	288	-	-	
Mississippi River Commission, U.S. Army	166	9	-	-	8	-	174	9	-	-	-	-	171	12	78	8	-	-	249	20	-	-	423	29	-	-	
TOTAL - DEFENSE	1,530	104	129	7	2,084	175	3,743	286					2,648	181	132	13	2,406	130	5,186	324	6,365	288	15,294	(749) 898			
DEPARTMENT OF THE INTERIOR																											
Topographic Division, Geological Survey (GS)	28,100 (4,047)	1,354	248	11	1,540	75	29,888 (4,047)	1,440	-	-	-	-	-	-	-	-	1,198	59	1,198	59	-	-	31,086	(4,047) 1,499	-	-	
Geologic Division, GS	-	-	-	-	-	-	-	-	- (1,163)	-	-	-	-	-	-	-	222 (212)	10	222 (1,375)	10	-	-	222	(1,375) 10	11,591	361	Geologic investigations for scientific studies and mapping.
Water Resources Division, GS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	44 (739)	2	44 (739)	2	-	-	44	(739) 2	3,342	125	Hydrologic investigations for scientific studies and mapping.
Earth Resources Observation Systems, GS	-	-	-	-	- (1,000)	-	- (1,000)	-	-	-	-	-	-	-	-	-	- (836)	-	- (836)	-	-	-	-	(1,836) -	-	-	
Publications Division, GS	3,997	235	-	-	-	-	3,997	235	1,163	56	-	-	-	-	-	-	871	51	2,034	107	-	-	6,031	342	-	-	
Bureau of Land Management	-	-	230	30	50	-	280	30	-	-	-	-	242	21	705	45	1,384	103	2,331	169	-	-	2,611	199	-	-	
National Park Service	-	-	-	-	-	-	-	-	-	-	-	-	274	21	263	20	428	114	965	155	-	-	965	155	-	-	
Bureau of Reclamation	-	-	-	-	19	-	19	-	-	-	-	-	905	30	127	11	-	-	1,032	41	-	-	1,051	41	-	-	
Bureau of Mines	-	-	-	-	-	-	-	-	-	-	-	-	205	11	-	-	-	-	205	11	-	-	205	11	-	-	
Bureau of Sport Fisheries & Wildlife	-	-	-	-	-	-	-	-	-	-	-	-	-	-	113	11	-	-	113	11	-	-	113	11	-	-	
Bureau of Indian Affairs	-	-	-	-	21	-	21	-	-	-	-	-	-	-	-	-	75	8	75	8	-	-	96	8	-	-	
Bonneville Power Administration	-	-	-	-	-	-	-	-	-	-	-	-	712	65	-	-	-	-	712	65	-	-	712	65	-	-	
TOTAL - INTERIOR	32,097 (4,047)	1,589	478	41	1,630 (1,000)	75	34,205 (5,047)	1,705	1,163 (1,163)	56			2,338	148	1,208	87	4,222 (1,787)	347	8,931 (2,950)	638			43,136	(7,997) 2,343	14,933	486	
DEPARTMENT OF AGRICULTURE																											
Agricultural Stabilization & Conservation Svc	-	-	-	-	2,633	137	2,633	137	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,633	137	-	-	
Soil Conservation Service	-	-	301	28	1,626	111	1,927	139	-	-	3,566	215	225	14	-	-	198	18	3,989	247	-	-	5,916	386	21,446	1,254	Soils delineation for soils mapping.
Forest Service	614 (15)	59	280	26	1,693	32	2,587 (15)	117	-	-	-	-	808	69	62	7	1,077	72	1,947	148	-	-	4,534	(15) 265	2,150	97	Soils delineation for soils mapping.
TOTAL - AGRICULTURE	614 (15)	59	581	54	5,952	280	7,147 (15)	393			3,566	215	1,033	83	62	7	1,275	90	5,936	395			13,083	(15) 788	23,596	1,351	
DEPARTMENT OF COMMERCE																											
National Ocean Survey, National Oceanic and Atmospheric Administration (NOAA)	-	-	-	-	-	-	-	-	-	-	-	-	84	6	-	-	-	-	84	6	8,868	487	8,952	493	-	-	
Environmental Research Laboratories, NOAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	140	5	140	5	-	-	140	5	-	-	
Bureau of Census, SESA	-	-	774	65	-	-	774	55	-	-	-	-	-	-	-	-	182	17	182	17	-	-	956	82	-	-	
TOTAL - COMMERCE			774	65			774	65					84	6			322	22	406	28	8,868	487	10,048	580			
DEPARTMENT OF TRANSPORTATION																											
Federal Aviation Administration	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,306 (3,446)	47	1,306	(3,446) 47	-	-	
Federal Highway Administration	-	-	4,701	447	363	21	5,064	468	-	-	-	-	2,045	173	109	10	586	58	2,740	241	-	-	7,804	709	-	-	
TOTAL - TRANSPORATION			4,701	447	363	21	5,064	468					2,045	173	109	10	586	58	2,740	241	1,306 (3,446)	47	9,110	(3,446) 756			
DEPARTMENT OF HOUSING & URBAN DEVELOPMENT	-	-	-	-	-	-	-	-	-	-	-	-	8,276	-	2,758	-	2,758	-	13,792	-	-	-	13,792	-	-	-	
INDEPENDENT AGENCIES																											
Atomic Energy Commission	-	-	-	-	-	-	-	-	66	3	53	-	65	14	-	-	95	5	278	22	-	-	278	22	-	-	
Delaware River Basin Commission	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3 (12)	-	3 (12)	-	-	-	3	(12) -	-	-	
Environmental Protection Agency	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,500	-	1,500	-	-	-	1,506	-	-	-	
General Services Administration	-	-	-	-	6	-	6	-	-	-	-	-	-	-	-	-	345	30	345	30	-	-	416	34	-	-	
National Aeronautics & Space Administration	-	-	-	-	71	4	71	4	-	-	-	-	-	-	-	-	98 (501)	7	98 (501)	7	-	-	4,475	(867) 323	-	-	
National Science Foundation	-	-	-	-	4,377 (366)	316	4,377 (366)	316	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(157) -	-	-	
Tennessee Valley Authority	- (157)	-	-	-	-	-	- (157)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
TOTAL - INDEPENDENT AGENCIES	434	26	164	10	63	2	661	38	52	3	-	-	474	30	348	20	119	9	993	62	-	-	1,654	100	891	52	Foreign Topographic Mapping.
	434 (157)	26	164	10	4,517 (366)	322	5,115 (523)	358	118	6	53		539	44	348	20	2,159 (513)	51	3,217 (513)	121			8,332	(1,036) 479	891	52	
BILATERAL ORGANIZATIONS																											
International Boundary & Water Commission, U. S. & Mexico	-	-	-	-	7	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	
TOTAL	34,675 (4,219)	1,778	6,827	624	14,646 (1,366)	873	56,148 (5,585)	3,275	1,281 (1,716)	62	3,619 (196)	215	16,963	635	4,617	137	13,728 (2,300)	698	40,208 (4,212)	1,747	16,539 (3,446)	822	112,895	(13,243) 5,844	39,420	1,889	

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NATIONAL TOPOGRAPHIC PROGRAM

Multipurpose maps of the National Topographic Series are produced and maintained by the Topographic Division of the Geological Survey, with some effort contributed by the Forest Service, the Tennessee Valley Authority, and the Mississippi River Commission. National mapping requirements, as determined primarily by Federal agency requests, are the basis for the National Topographic Program which includes several individual map series. Most of the program effort, however, is dedicated to the production and maintenance of the 1:24,000-scale, 7.5-minute topographic map series.

New or modified series are added to the program as requirements change. The orthophotomap recently has been added as a new edition in the 7.5-minute series. It contains a color-enhanced photoimage base underlying selected line symbols. This treatment is used for areas where the image base is clearly superior to a line base for optimal depiction of the landscape. The orthophotoquad, a more recent modification, is a uniform-scale photoimage in quadrangle map format with only sufficient cartographic work for orientation. Orthophotoquads are now being produced as complements to existing maps and as map substitutes for areas that do not have standard map coverage.

There is no practical limit to the scales or types of map content that can be added to the National Topographic Series, but the record shows that GS has generally been slow to modify the Series, either by adding new elements or chopping old ones. This is one of the reasons user agencies have produced their own maps rather than using the national products.

During FY 1972, agencies contributing to the National Topographic Map Series were:

Agency	Dollars (in Thousands)	Man-years
GS (Topo)*	$35,083	1,499
TVA	434	26
FS	617	66
MRC	166	9
Total	$36,300	1,600

*Does not include $6.3 million and 337 man-years by GS for geodetic and mapping control discussed earlier in Land Surveys.

The Forest Service has reduced its quadrangle mapping program in recent years and plans to rely fully on GS for these maps in the near future.

The Tennessee Valley Authority only revises 1:24,000-scale maps, as the quadrangle mapping has been completed for the Valley area. Mississippi River Commission receives completed 1:24,000-scale maps from GS in the MRC area of interest and converts them to 15-minute, 1:62,500-scale maps. The maps are printed by MRC (contract) and distributed by MRC and GS.

Topographic Quadrangles (1:24,000- and 1:62,500-Scale)

The 1:24,000-scale, 7.5-minute quadrangle map is the nucleus of the National Series. In 1972, $33.9 million, with 1,483 man-years, was spent by GS in production of new and revised 7.5-minute quadrangle maps. These are the only maps in the series built from scratch, and many other maps are derived from them. For example, they are used by GS in adding information to or deriving maps in the 1:250,000-, 1:500,000-, and 1:1,000,000-scale series as well as National Park maps, geologic maps, and hydrologic atlases. Other agencies use them in construction of maps for their own programs.

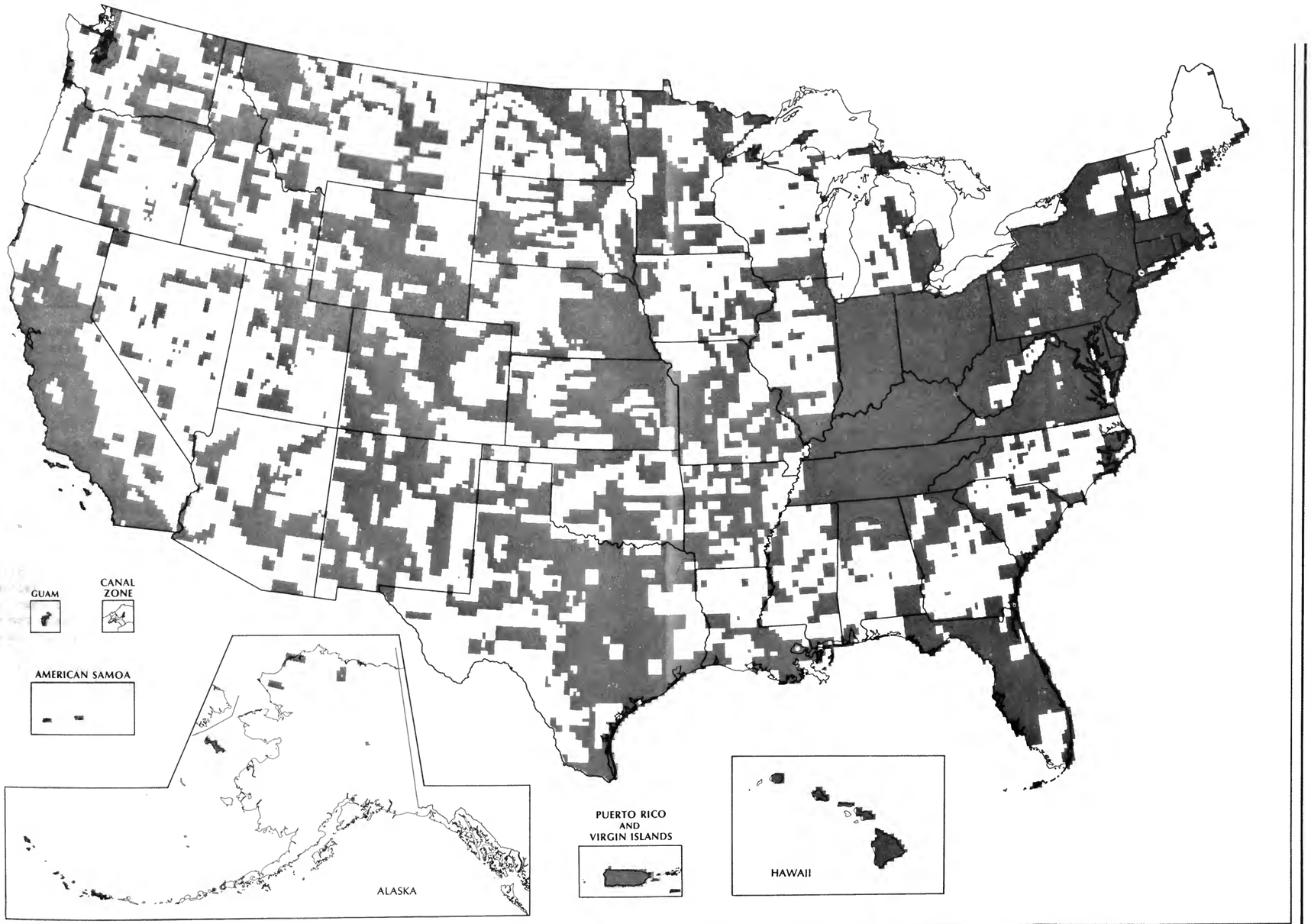
New mapping projects are based on priority needs, as determined from formal annual requests from 30 Federal agencies (A-16). Requests received directly from State mapping advisory committees and other State and local government officials are also considered, but to a lesser extent. The program is financed primarily by congressional appropriation, but State and local agencies cooperate by supplying about 8 percent of the funds. In these cooperative projects, the work to produce new or revised maps is accomplished by GS, and the States pay 50 percent of the cost. In FY 1972, there were cooperative agreements with 36 States and local governments.

In preparing quadrangle maps GS performs all mapping operations, including procurement of aerial photography, field geodetic and mapping control, photogrammetric control extension, compilation, map finishing, field completion and verification, publication and distribution. In its contributions, Forest Service produces manuscripts, after which GS completes, prints, and distributes the maps.

General-purpose map coverage at scales of 1:24,000 or 1:62,500 (1:20,000 in Puerto Rico and 1:63,360 in Alaska) is now available for about 87 percent of the total area of the U.S. and outlying areas of sovereignty. About 8 percent of the coverage is not yet published but is available as advanced manuscript prints.

Because of the need for more detailed, accurate maps, the primary effort of the program is now directed toward completion of 1:24,000-scale maps of the country (1:63,360 in Alaska). About 56 percent is published at 1:24,000 scale (fig. 13), and an additional 18 percent is in work or awaiting publication. Each year GS completes about 100,000 square miles of new 1:24,000-scale mapping, and at that rate all states except Alaska can be covered by about 1983.

Alaska coverage at 1:63,360 is now about 80 percent finished, and it is expected to be completed by the early 1980's (fig. 14).



NATIONAL TOPOGRAHIC PROGRAM

1:24,000-SCALE MAPS

(1 inch=2,000 feet)

Published maps or available in preliminary form.

Note: Annual production of new maps is about 100,000 square miles, an area equal to Colorado.

Nearly 8,000 maps are out-of-date. These cover about 470,000 square miles, an area equal to Arizona, California, Nevada and Utah.

June 1972

Figure 13

Requirements for Topographic Quadrangles

Our requirements survey conclusively documented a heavy Federal agency demand for quadrangle maps. The demand may be examined two ways -- one, as related to distribution, and the other, as related to agency requests for new maps or revisions.

The total 1972 distribution of 7.5-minute, 1:24,000-scale quadrangles is shown in the following table:

Distribution of 1:24,000-Scale Quadrangle Maps
(Thousands of Copies)

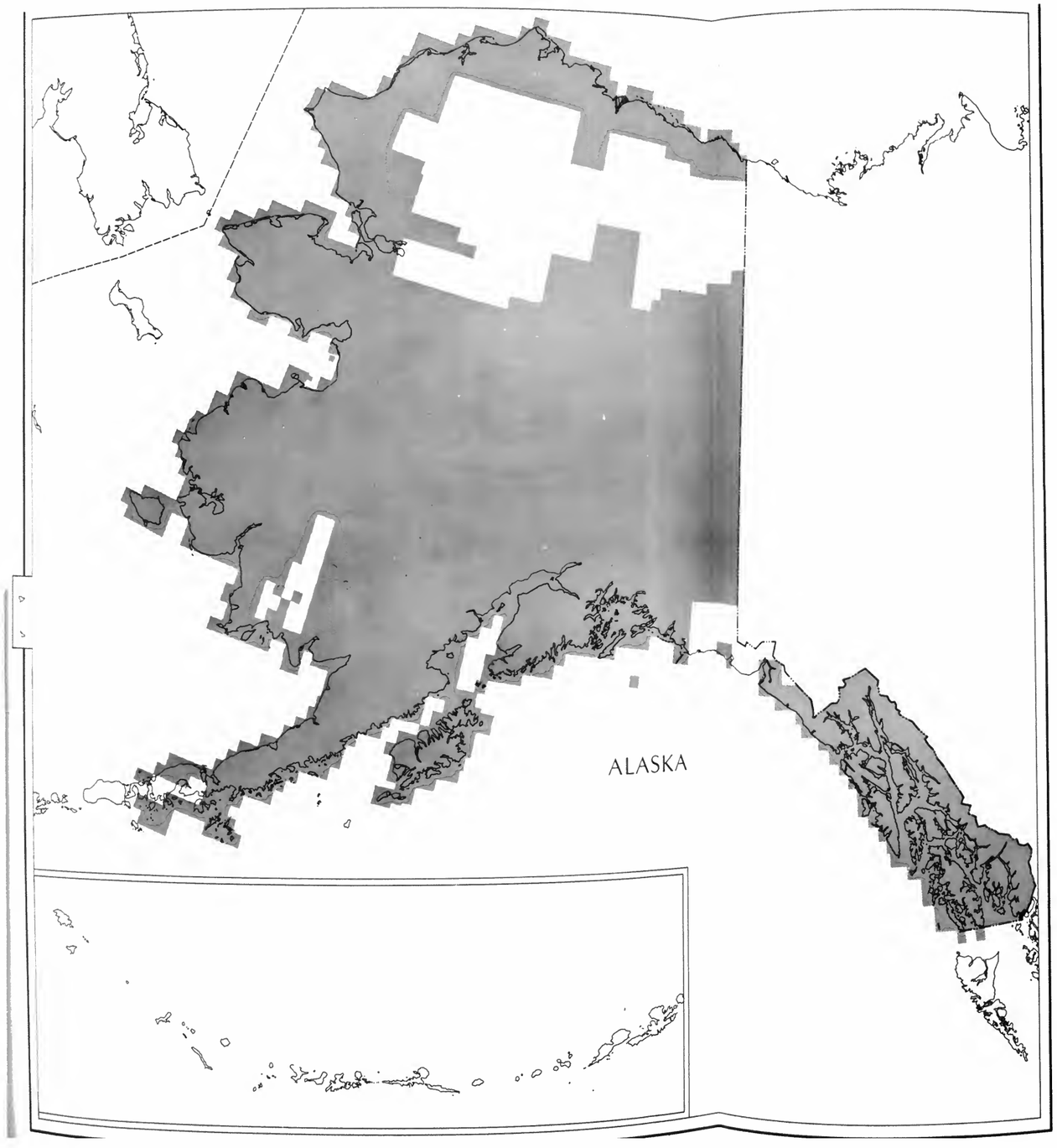
Type of Map	Federal	State	City/ County	Industrial Commercial	Public	Total
New Topographic	1,199	626	70	1,339	2,251	5,485
Interim Revision	233	91	10	194	327	855
Orthophotomap	28	12	1	25	42	108
Total	1,460	729	81	1,558	2,620	6,448

Total 1972 distribution of all National Topographic Series maps amounted to 7,900,000 copies.

Nearly 14,000 reproducible film copies of final drawings of 1:24,000-scale quadrangle maps were distributed, of which 65 percent went to Federal agencies. The purchase of reproducible copies is a good indicator of dynamic map use.

Distribution of advanced copies (monocolor reproductions of unedited maps) totaled 390,850, of which 26 percent went to Federal agencies. Requests for advanced copy are based on mapping needs that cannot wait for published products. We found that most users are not aware of the availability of advanced copy and so are not taking full advantage of it.

We recommend, therefore, more energetic advertisement of the availability of advanced topographic map copy.



NATIONAL TOPOGRAHIC PROGRAM

1:63,360-SCALE MAPS of ALASKA

(1 inch = 1 mile)

Published or available in preliminary form.

Note: Mapping activities are planned for 35,000 square miles during FY 1973.

June 1972

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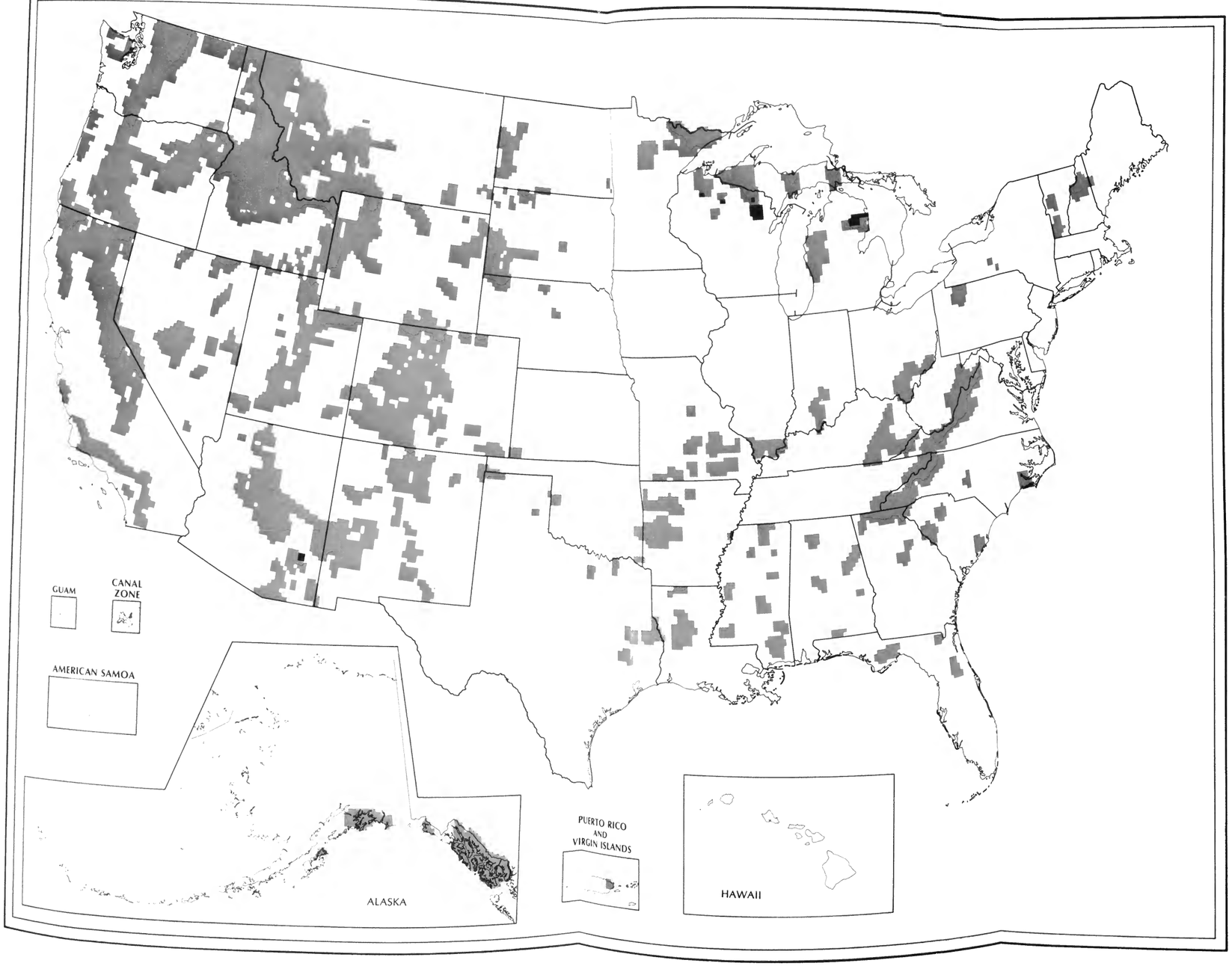
Figure 14

A much more meaningful measure of the requirement for maps is the body of requests made by Federal agencies each year, in accordance with OMB Circular A-16. In 1972, 26 agencies made first-priority requests for 10,868 new quadrangles against the GS annual capacity of 1,800 new quadrangles. Additional requests were submitted in 1972 for 2,585 map revisions, of which only 1,000 could be started that year. In other words, the total GS capacity for new starts presently meets only about 16 percent of the first-priority needs for new mapping and 39 percent for revision. This strongly suggests that a more realistic system of validating and responding to requests for mapping is needed (see Coordination of Federal Mapping).

Federal agency uses for topographic quadrangle maps cover several broad categories, including intensive planning, scientific studies, geographic reference for information systems, defense, transportation, environmental management, and many others. For example, Forest Service uses the quadrangle maps in highway planning and construction, timber-sale layout, and fire-control planning; as a base for their multilayer system (fig. 15) of accessing and processing thematic data such as soils, geology, timber inventory, and land use; and for the derivation of base maps for various levels of district, region, and division management. Atomic Energy Commission uses the maps as bases for planning and executing uranium exploration and plotting of drill holes for subsurface study. AEC has estimated the value of the maps for its own use at $50,000 per quadrangle. Environmental Protection Agency has requested total national coverage and uses the quadrangle maps as the preferred series for their Automap system -- by which all drainage features in the U.S. are digitized in a large information system for use in monitoring water quality, planning surveillance activities, and enforcing environmental protection. SESA uses the quadrangle maps in metropolitan areas as basic source material, updates them with cultural changes, simplifies the presentation by rescribing, and publishes a separate metropolitan series that in itself serves many urban planning and development uses. The maps are used extensively, sometimes updated, modified, or annotated, by applicants for HUD grants for planning urban development, public works, open space, and new communities.



NATIONAL FOREST MAPS

MULTI-LAYER SERIES

(At scales of
1:24,000 and 1:31,680)

Available

To be mapped

Note: Nearly 4,700 maps are out-of-date. These cover about 265,000 square miles, an area equal to Texas.

June 1972

522-980 O - 73 (Face p. 71 blank)

Figure 15

We found the adequacy of the basic elements of topographic maps to be as follows:

- o Scale -- Maps at 1:24,000 scale were found to be adequate for most general-purpose uses, although a smaller scale would not be. Some users, however, need maps at larger scale (1:10,000 or 1:6,000), particularly in built-up areas. Others enlarge quadrangle maps up to five times.

- o Content -- Map content is adequate for most general-purpose needs, with some exceptions. Many users want more detailed treatment of specific content (such as drainage, ownership, street names) while a few want less overall detail (timber, contours, buildings). Many agencies have developed their own map series to overcome these deficiencies. This practice, which has resulted in inefficiencies, is discussed fully in the section on Special Base Mapping.

- o Availability -- Most users require complete coverage of their area of interest, which in aggregate is nationwide. The most significant inadequacy was found to be lack of coverage and the obsolescence of some 8,000 published maps. We regard the findings on obsolescence and coverage as highly important and treat these problems and their solution in the following sections.

Revision

The major reason for map obsolescence is cultural change, but changes in user requirements are also an important factor. Increased use of computer-assisted information systems by Federal agencies demands accurate, standardized, current information. Also, many maps in relatively flat terrain were originally compiled with 20-foot contours, whereas the more intensive use now being made of the maps for planning and engineering requires more precise elevation data such as can be provided by a 5-foot contour interval.

General time criteria established by the GS for map revision are:

Urban and urbanizing areas	5 years
Agricultural areas	10 years
Remote areas	20 years

These criteria are used only as a general guide. Candidates for map revision are selected on the basis of actual change, by examination of current photography.

We found these criteria generally adequate for the first two categories. A 20-year cycle, however, is not adequate for many of the public lands, particularly those that are intensively managed and where the impact of development on the environment is critical.

Urban-area maps are being kept up to date on a 5-year cycle. For example, the 52 maps covering the metropolitan and suburban area of Washington, D.C., are 3 years old or less. For the categories of agricultural and remote areas, the record is not so favorable.

Overall, approximately 8,000 maps are out of date, equaling an area the size of the States of California, Arizona, Nevada, and New Mexico. The volume of obsolescent maps is growing every year (1,200-1,300 go out of date compared to the 900-1,000 that are revised). Most of these are in areas covering smaller cities and towns and in rural and remote areas. Users with interests in these areas are forced to update maps for their own needs, and this, of course, must be done for every individual use. This surely leads to inefficiency and causes some user agencies to develop their own mapping capability and add information to the map base that does not find its way to the published national map.

Map revision has been traditionally accomplished by using a combination of photogrammetric, field, and cartographic procedures similar to those used for new mapping. In standard revision, all map content is updated, and the basic accuracy of the map is maintained or improved. An important new step has been taken in recent years toward solving the problem of map currency by the

adoption of photo revision procedures, without field check, and without extensive cartographic treatment. Under this process, called interim revision, information about changes in cultural and planimetric features is obtained from current photographs, and the changes are printed on the revised map in purple. This technique relies heavily on photointerpretation and is a low-cost, more rapid method of producing revised maps. With this process, a map can be revised for about $2,100 -- less than a third the cost of a standard revision -- and can be available in printed form in a year or less after the date of photography. During FY 1972, 1,060 maps of the 7.5-minute series were revised, 930 by interim revision procedures.

The problem of map obsolescence can be significantly alleviated by greater use of advanced technology in the map revision process. Map revision by this method is now being done at the GS Special Mapping Center in Reston, Va., which produced 259 revised maps through FY 1972. Production at Reston for 1973 was 163 maps. The technique for using these data for interim revision is now developed to a point where maps so revised cost on the average $2,000 per quadrangle as opposed to an average of $2,100 for those revised by conventional methods. The $2,000 cost includes higher overhead caused primarily by a small production base. This base can be expanded without increasing overhead, bringing potential savings per map to $300.

We recommend that GS dramatically expand the use of advanced technology for interim revision operations in the National Topographic Program. We estimate that annual savings by use of this capability can be as much as $300,000.

Map Production Cycle

The length of time it takes to produce finished maps is a serious problem. At the Geological Survey, the average time to produce a published, multicolor quadrangle map is about 5 1/2 years

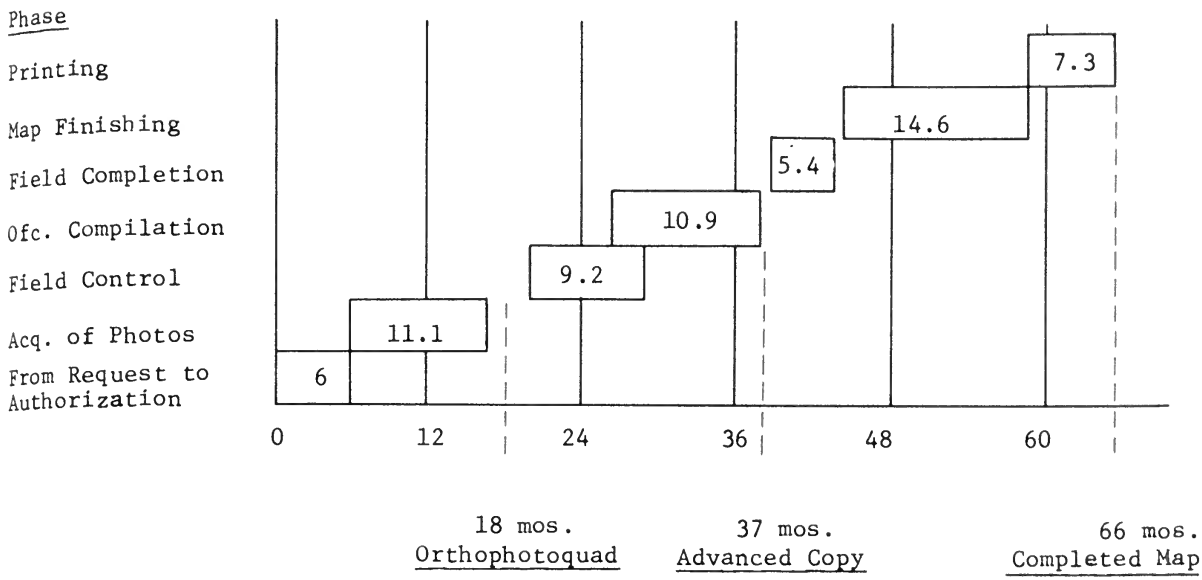
from receipt of request through printing. Figure 16 shows the actual production cycle and how the time is divided among the various production phases. If one considers the date of photography as a valid map date, printed maps are based on 4-year-old-data -- and that's the average -- some new maps are based on even older data. Some users request and get monocolor advanced manuscript copy after 2 years, but multicolor printed maps are usually not available until 3 years later. The seriousness of this problem is increased by the inability of major consumers to predict their needs for specific quadrangle maps much more than a year in advance. Unless they are fortunate in having their project area covered by somebody else's earlier request, they are bound to make arrangments for building their own maps.

As shown, the mapping cycle can be reduced by availability of current photographs, reduction of field control surveys and field interpretation, improved instrumentation for photogrammetric compilation and control extension, better organized and more efficient map-finishing procedures, and by more efficient printing capability. Means of introducing these measures in the mapping process are now, or soon will be, available. They can be implemented by pooling MC&G resources, by applying advanced photogrammetric technology and by introducing automated cartographic techniques now being developed. These actions would require a significant amount of capitalization, however, and time for implementation.

Another way of reducing the waiting period for some users would be the rapid release of needed data which are generated during the mapping process. Releasing advanced manuscripts in 2 vs. 5 years is a step in the right direction, but the concept can be expanded to include various digital, photo, and map products which can be output at various intervals in the process.

ACTUAL AND POTENTIAL TOPOGRAPHIC MAP PRODUCTION CYCLES

Conventional Methods
(Actual Cycle in Months)



Improved Methods
(Potential Cycle in Months)

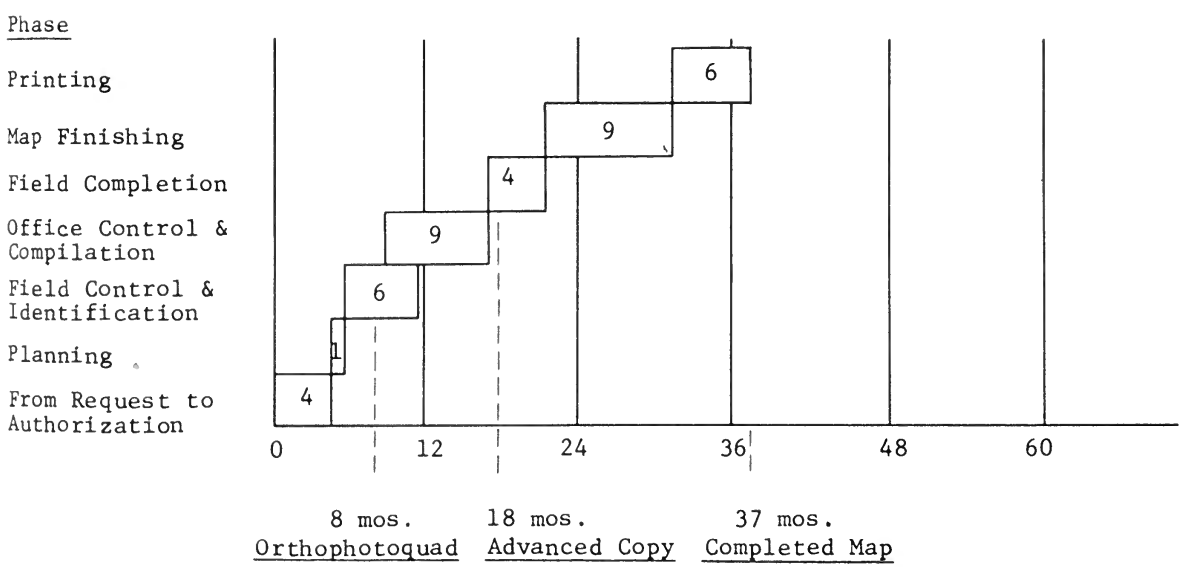


Figure 16

Changing Requirements

The national mapping program though general-purpose in nature has been single-product oriented, with the result that many unique requirements are not fully met. Portrayal of drainage is a good illustration of this problem. Both Forest Service and Bureau of Land Management are concerned with drainage as a prime factor in land management and require more detailed data than is portrayed on general-purpose national map products. On the other hand, SESA is not highly concerned with natural features and prefers to display less drainage in order to provide room for and give emphasis to other features. Both requirements are sound, and neither can be met by a single general-purpose product. Inefficiencies result from several agencies adding and removing information from the national products. These problems indicate a need to reexamine the policy of trying to meet all requirements with a general-purpose topographic map. Very likely, some high-priority special requirements can be more efficiently met by developing various levels of information during the initial mapping process.

Another example of a way the National Topographic Program can offer more effective response to changing requirements of other Federal agencies is in the area of photoimage products used as map supplements or map substitutes. Soil Conservation Service is using controlled photomosaics with accuracies of 75 to 175 feet at a cost of $200-$300 per quadrangle area in the production of published soil surveys. Bureau of Land Management and Forest Service are preparing rectified photomaps at accuracies of 50 to 150 feet for $150-$250 per quadrangle for support of their land-management functions. GS now prepares orthophotoquads at national accuracy standards (20 to 40 feet) at a cost of $400-$600 per quadrangle. Expenditures by these four agencies for such products in 1972 exceeded $1 million, and the combined programs envision a three- to five-time expansion of that activity in the next 5 years. We believe the efforts should be combined and orthophoto products should be produced to a single standard by the national program, yielding useful photo bases in areas of need at accuracies that preserve the compatibility of related data with the national map data base. These products would be multipurpose and lend themselves readily to economical, timely production.

A third area of changing requirements that demands rationalization and organization is the area of digitization. Several agencies are digitizing spatial data now and plan to expand these efforts. The potential for waste and duplication among these fragmented programs is great. Many of the agencies now getting into digitization have not been associated with MC&G and in no way consider their effort to be mapping. Nevertheless, the mapping discipline can offer strength and compatibility to the various unrelated activities. The correct place for centralization of this effort is in the national mapping program, where common standards and reference system can be implemented.

Our study of quadrangle mapping of the National Topographic Program led us to conclude that the 1:24,000-scale quadrangle maps are needed by many Federal, State, and local government agencies. Effective multipurpose use is being made of them by some agencies in conducting their work. This use should be encouraged and extended.

We recommend that the National Topographic Program be established as a major function of a new central agency, and that the production and maintenance of 1:24,000-scale quadrangle maps continue against the most urgent Federal priorities.

We also conclude that the value of quadrangle maps to users is severely reduced by lack of coverage, by their being frequently out of date and by the length of time it takes to produce them. Although the 1:24,000-scale maps meet many multipurpose needs, they do not meet all needs -- particularly those for special themes and for basic data at larger scales as needed for many urban development problems. The lack of complete, current map coverage, the long production cycle for new maps, and the need for special treatment and detail cause many user agencies to develop and expand expensive in-house mapping capabilities which would not be needed if the national program were more responsive. Moreover, these mapping efforts generally do not contribute to meeting requirements of other agencies, leading to the inefficiency of work being done several times over.

We recommend that the new agency expedite the production of maps and mapping data as follows:

- *Develop greater flexibility in the quadrangle mapping process so that different products can be made for different agencies (e.g., census maps for SESA, complete drainage and road patterns for FS, highway data for FHWA).*

- *Produce quadrangle orthophotomaps in areas where this product provides most useful information, with only enough line symbolization to clarify and quantify the photoimage.*

- *Consider the initial production of an orthophotoquad for each mapping project (to be furnished to customers quickly -- 6 to 8 months), with a follow-on contoured orthophoto product if needed. Completion of the final line map should be deferred until requirements for it are justified.*

- *Emphasize development of digital data in connection with the mapping process. As consumers require, digital data can be taken from existing maps and added to the data base. As a minimum, the process should produce terrain data.*

- *Press for a complete data base, and through advanced instrumentation, apply the data base as fully as possible to the standard quadrangle mapping program.*

- *Increase emphasis on map revision. The backlog of out-of-date maps must be eliminated and the maps kept current, even if this means slowing the rate of producing complete line maps.*

Generally speaking, except for advanced instrument capitalization, the above recommendations can be implemented through reprogramming.

Small Scale and Special Maps

The largest map scale that covers the entire area of the U. S. is 1:250,000. The sheets of this map series were originally prepared as military editions by the U.S. Army Map Service (now DMA Topographic Center) during the 1950's. DOD and NOS are the primary users (as bases for aeronautical charts), but use is also expanding for these maps as a geographic reference and as bases for regional land-use, transportation, and utility system planning.

The series is now maintained by the GS on about an 8-year cycle with changes and additions to make it suitable for both civilian and military application. For Alaska, GS is replacing the 1:250,000-scale Alaskan Reconnaissance Series with an improved series at the same scale.

The 1:250,000-scale maps are revised at the Reston Special Mapping Center. Although GS does not have sufficient advanced equipment, nevertheless GS has improved the 1:250,000-scale series on a meaningful cycle. This upgrading would have been many times more expensive if done by conventional methods.

Other small-scale maps produced in the National Topographic Map Series are as follows:

- State maps are published for all States, usually at a scale of 1:500,000. All of these maps are published in planimetric editions, and contour and shaded relief editions are also available for most of them.

- Maps of national parks, monuments, historic sites, and other areas administered by the National Park Service have been published, usually by combining the existing quadrangle maps of the area into one map sheet.

- The worldwide million-scale series of topographic quadrangle maps sponsored by the United Nations has been designated the International Map of the World (IMW). Of the 53 maps covering the conterminous U.S., 50 have been produced and the other three are in progress.

Cooperation in Federal Mapping by States and Local Governments

A study of the mapping services of the Federal Government, conducted in 1935 under the aegis of the Science Advisory Board, addressed the question of State, County, and local cooperation in Federal mapping, finding evidence that ". . . under some conditions such cooperation may tend: (a) to interfere unduly with the National Mapping Program by forcing departures from national standards as to scale, quantity of detail, size of sheet, etc., to meet local needs; (b) thus to create a situation in which Federal funds are expended in helping to provide states with special maps, while no maps of standard scale are added to the national series; (c) to interfere unduly with the best program of priority in national mapping; (d) to limit Congressional appropriations to matching state appropriations with the result that the National Mapping Program is determined too little by national needs and too much by the ability of certain states to pay; (e) to bring about the practical cessation of topographic mapping in some states while mapping or remapping is concentrated in others; (f) and consequently to leave the poor states without one of the indispensable aids to development, and the poorer border states without maps deemed essential to the national defense."

We agree that the concerns expressed in the 1935 study were valid, and we have examined them in light of the present situation. Geological Survey has cooperative agreements with 36 states and local governments for topographic surveys and mapping. In 1972, cooperative offerings were about $3.2 million. By the language of

its appropriations acts, GS is permitted to cooperate on a 50-50 matching basis. Under these agreements, GS does all the work, primarily under state-recommended priorities, and bills the cooperating government for 50 percent of the costs. The products are new standard quadrangle maps or revisions. It is GS policy to accept no cooperative funds for nonstandard products. Accordingly, items (a) and (b) above do not pertain at all in present circumstances.

It is clear that cooperative projects do interfere with a purely national set of priorities (item (c)). However, because quadrangles requested by Federal agencies frequently are mapped under a cooperative program and cooperative funding substantially extends the capacity of the national program, we conclude that cooperative programs have not unduly affected national priorities. An unmistakable positive effect of cooperative programs has been the complete mapping of several states (now totaling 11) and the near completion of several others. This has undoubtedly drawn Federal attention away from some areas of higher national priority. On balance, however, we conclude that as long as the potential pitfalls of items (d), (e), and (f) are recognized and no areas of high Federal priority are ignored, the cooperative programs will have the general effect of advancing the national program.

We recommend continuation of cooperative programs that do not interfere with national priorities and do not inequitably distribute the national mapping effort.

Coordination of Federal Mapping

Rapid growth and development of the Nation and the initiation of countless Federal, State, and local action programs requiring mapping support have complicated the problem of mapping coordination.

In recognition of the need for more effective coordination of Federal surveying and mapping, the Bureau of the Budget issued Circular A-16 (Revised) in May 1967. Through this circular, the Department of Interior was assigned governmentwide responsibility for coordination of domestic mapping activities which are financed

in whole or in part with Federal funds and which can reasonably contribute to the National Topographic Program. All Federal agencies which funded mapping were made responsible for cooperating with the Department of Interior in developing appropriate coordinating mechanisma; supplying information concerning cartographic requirements, programs, and products; and conducting surveying and mapping activities in a manner which would provide effective governmentwide coordination and efficient service to the public. Responsibility for fulfilling the provision of Circular A-16 was delegated by the Department of Interior to the Geological Survey.

Following the issuance of Circular A-16 and the delegation of coordination responsibility to GS, some steps were taken to develop more effective coordination:

- Federal Mapping Coordination Conference, September 1967. Thirty-five Federal agencies participated.

- Technical Exchange Briefings -- 1967, 1971, and 1972. Briefings were held by major Defense and civilian mapping agencies.

- Coordinator for Federal Mapping -- position established in GS Topographic Division. Meetings have been held with 43 agencies to discuss overall coordination objectives.

Although some communication among agencies that use and produce maps has occurred, coordination of Federal mapping activities has not been generally effective; and with the growth of mapping requirements, single-purpose response has increased and spread to more agencies.

Several major problem areas have kept A-16 from being more effective:

- The coordination task required is too large and complex to be effectively accomplished by an interagency coordination mechanism.

- Cooperation is voluntary and agency participation is often passive. GS has no clear enforcement authority.

- User requirements have seldom been well enough articulated or systematically enough collected to result in new or changed products.

- OMB involvement until recently has been slight.

- Interior coordination responsibility was delegated too low and inadequately staffed (two professionals).

- The influence of the Circular is limited to topographic mapping and contributions to the National Topographic Map Series. Maps and other spatial information which are national in scope and of value to many users are not covered by the Circular and are thus not treated through the coordinating mechanism.

- GS inability to respond to all mapping requirements reduces other agency dependence on the national program.

We recommend that the new agency be given clear authority and responsibility to manage national mapping programs with enough clout to coordinate all related activities of Federal agencies. Further, it must actively take the lead in identifying and evaluating requirements and influencing program thrusts toward optimum response to national needs effectively and economically. The scope of its monitoring authority must be broadened to include maps, photo products, digital products, and information systems which are not now a part of the national mapping program.

SPECIAL BASE MAPPING

The National Topographic Program does not provide a sufficient variety of scales, map content, and complete up-to-date area coverage to meet legitimate Federal requirements for base maps. To meet their own requirements, therefore, several agencies produce their own base maps at selected scales to display special information related to their missions and areas of interest. The agencies producing special base maps and their program outlays are shown in the table below:

	FY 1972 Programs -- $ in Thousands				
Agency	Planimetric Maps	Digitized Map Data	Photo Bases	Other Photo Products	Total
FHWA	$4,701	-	-	$ 363	$ 5,064
SESA	774	-	-	-	774
ASCS	-	-	-	2,633	2,633
FS	280	-	$ 14	1,679	1,973
BLM	230	-	9	41	280
BIA	75	-	-	21	96
SCS	301	-	677	949	1,927
TVA	164	-	-	63	227
EPA	-	$1,500	-	66	1,566
NASA	-	-	-	4,377	4,377
DOD	-	343	-	2,084	2,427
Others	-	-	-	130	130
Total	$6,525	$1,843	$700	$12,406	$21,474

The following table summarizes special planimetric base-mapping programs.

Agency	Map Product	Scale(s)	Area(s) of Interest	Update Cycle	Percent Completed
FHWA	County highway	1 in = 2 mi	84% of U.S.	variable	100
SESA	Metro series	1 in = 800 to 2000 ft	300,000 sq mi	not started	20
FS	Forest series	1 in = 2 mi	930,000 sq mi	5 to 10 yr	80
BLM	Base series	1 in = 1 mi	532,500 sq mi	variable	85
BIA	Highway system	1 in = 2 mi	84,000 sq mi	1 yr	40
SCS	Base series	variable	many local	variable	continuing
TVA	Base series	variable	local	variable	continuing

County Highway Maps

Maps of the Country Highway Series are financed primarily by Federal funds ($4.7 million in FY 1972) and are normally compiled and updated by State highway departments, although some counties compile their own maps. The maps are used at the Federal and State levels for graphic inventory and management of the Nation's highway system and at the local level for general planning of construction and maintenance projects and for reference in locating points and areas of county activity.

In the 1930's, a nationwide program was initiated to compile full U.S. coverage of highway maps on a county format at a scale of 1 inch equals 2 miles. Except for voids in Alaska, coverage is now complete at that scale or larger. The series is updated catch-as-catch-can as individual highway departments are motivated or funded.

We believe that the maintenance of the highway series should presently remain the responsibility of the State highway departments because of their familiarity with local problems, updating requirements, and funding priorities (funds are allocated from Federal-aid highway programs). The series could, however, be made more effective by consistent application of standard treatment, and the program could be made more efficient by application of modern techniques and use of other base maps for updating.

We recommend, therefore, that the federally funded mapping activities associated with the County Highway Series be monitored and coordinated by a central MC&G agency with the goals of (1) establishing standards for design, content, and accuracy and (2) applying new methods and technology to improve efficiency.

Metropolitan Maps

The Social and Economic Statistics Administration (SESA) recently started the Metropolitan Map Extension program, which produces base maps to extend the area coverage of the 1970 census maps (Metropolitan Block Statistics Series). Twenty-five new maps were produced in FY 1972. SESA plans to accelerate the program to complete the map coverage of the Standard Metropolitan Statistical Areas (SMSA's) before the 1980 census -- about 3,000 sheets covering an area of 300,000 square miles at a scale of 1:24,000 or larger.

In addition to their primary use in the National Census, the metropolitan maps and associated data are used in transportation planning (FHWA program), housing condition surveys (HUD program), welfare administration (HEW program), allocation of police patrols

(LEAA program), civil defense (OCD program), and population computations for revenue sharing. They are also used for planning, operational management, and improvement services by the commercial sector -- banks, newspapers, real estate agencies, market research organizations, and the like.

In addition, there are many requirements for systematic mapping in cities and metropolitan regions at scales larger than 1:24,000. At the present time, these requirements are being met piecemeal by state and local governments generally with Federal funds (HUD, FHWA) and with contracted capacity.

We conclude that production and processing of the basic data and detail required for metropolitan mapping could be most effectively done under the scrutiny of a single mapping agency since some of the map detail compiled and digitized for metropolitan maps can be used in updating the smaller scale quadrangle maps and other related maps. Furthermore, map-finishing phases of both operations use similar equipment, techniques, and skills. We further conclude that private-firm capability, rather than Federal buildup, should be the means of performing the needed work. There is plentiful commercial capability with the skill and knowhow necessary to do the work well and responsively.

Accordingly, we recommend the articulation of a national urban-mapping program by the new agency, setting standards and specifications for urban maps. The agency should work with program agencies -- Federal, state, and local -- assisting in contract writing, product and process inspection, and acceptance or rejection. All products and data should be accessed in a national MC&G data center for ready availability to all agencies. Work should be accomplished by contract capability, primarily, and not by Federal employees.

We further recommend transfer of the Metropolitan Map series program to the new agency, with the charge and responsibility for producing the maps required for census activity and correlating this activity with other related national mapping.

Base Maps for Land Management

The Bureau of Land Management, the Forest Service, and the Bureau of Indian Affairs have total mapping requirements for more than 1.5 million square miles. The National Forest Series (1 in.= 2 miles) is an example of a systematic program against such requirements (fig. 17). The base-map series produced by these land-management agencies are well established. All series are scheduled for completion within 5 years, but ongoing revision will continue indefinitely.

In-house map production by these agencies was caused by the absence of products of suitable scale and format in the National Topographic Series. Scales suitable for displaying an entire management area on one sheet (or a few sheets) are not produced in the national program (1 in. =.1 mi. to 1 in. = 2 mi.). Although these land-management base maps are derived from national topographic maps (1 in = 2,000 ft.), other available base maps and photographs must also be used in compilation and revision because of incomplete coverage and obsolescence of some maps in the national series.

These base maps are essential tools for effective management. They are used for identification, classification, leasing, acquisition, and disposal of public lands; for inventory, development, conservation, and protection of natural resources, such as timber, grazing lands, water supplies, wildlife, minerals, and fossil fuels; and for planning improvements and facilities, such as roads, trails, bridges, buildings, dams, and recreational areas.

Although the land-management agencies (BLM, FS, BIA, NPS) have similar missions, their base-map series have little commonality in scale, format, content, and symbols. Other agencies concerned with land use (TVA and SCS, for example) compile maps at an even more diverse range of specifications. We believe there is a good opportunity to pool national cartographic resources in the production of special base maps and thus improve efficiency, promote uniform standards, reduce duplication and overhead, and consequently save money (estimated at over $1.0 million annually).

We recommend that agencies involved in management of Federal lands as well as those concerned with national land use examine their requirements for maps and charts and define a family of national products for common use, to be produced by the central mapping agency.

Other Photo Products Used as Map Substitutes

Other photo products, in addition to the orthophotomaps and orthophotoquads mentioned earlier, are used by Federal, state, and local agencies as map substitutes in areas devoid of suitable maps and as complements to existing maps. They include a variety of photographic prints in black and white, color, false color, and infrared, both rectified (tilt displacement removed) and unrectified. For many uses, the photographs are enlarged up to four diameters and sometimes made into mosaics to cover areas of interest. Our study reflected an expenditure in FY 1972 of over $12 million by a dozen Federal agencies.

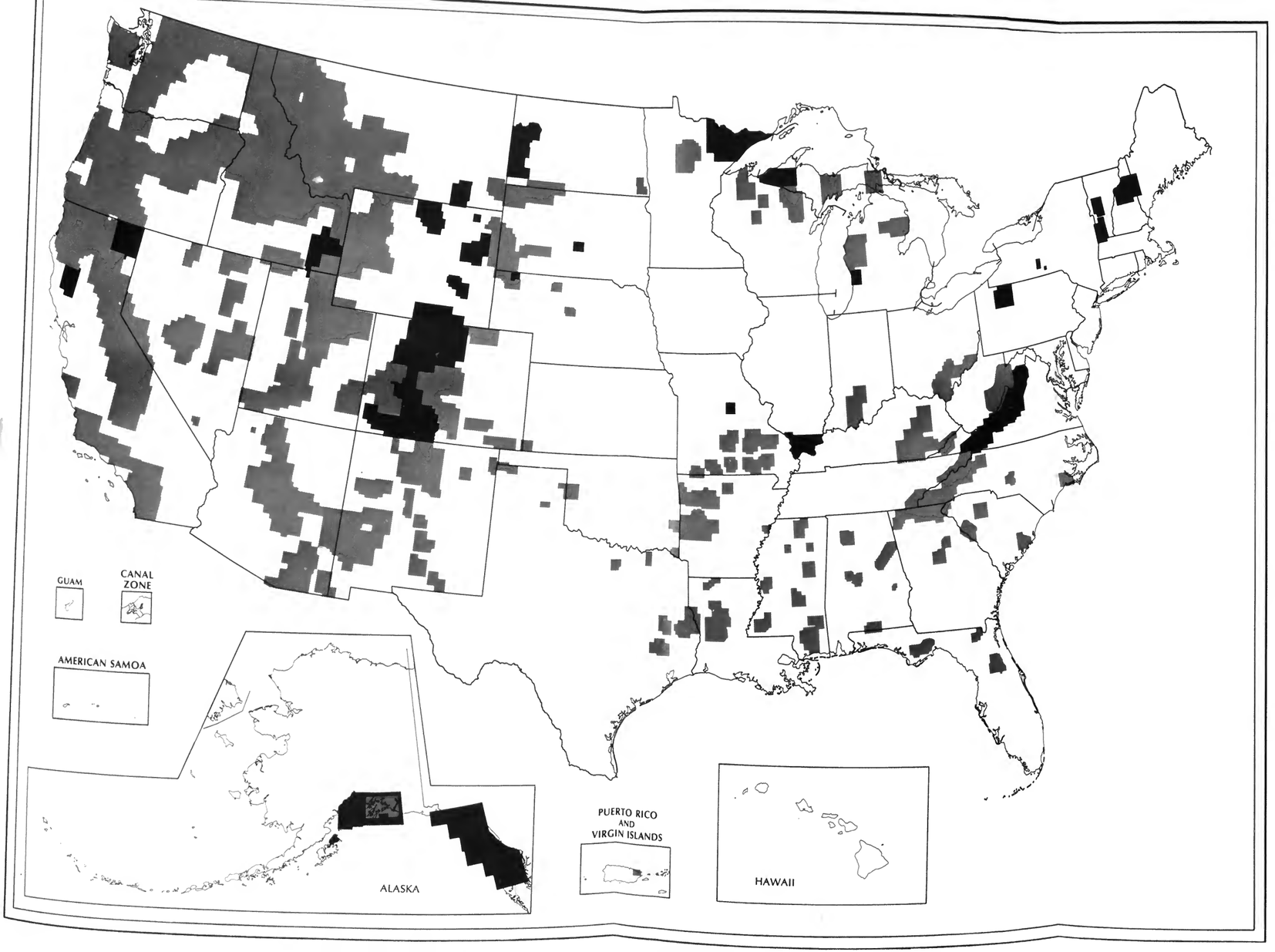
A few typical uses of such products are:

- Forest Service -- Photogrammetric extension of control; map compilation; photointerpretation of timber types, soils, watershed studies; planning tool for timber sale, recreation sites, road location.

- Soil Conservation Service -- Bases for soil surveys; development of soil and water conservation plans; planning tool for engineering surveys, soil investigations; preparation of range site and condition maps.

- Agricultural Stabilization and Conservation Service -- Base for measuring crop acreage in administration and implementation of the crop allotment, production adjustment and marketing quotas.

- Department of Defense -- Photo materials over military training areas for air and ground training exercises, preparation of topographic map and air-target charts in training areas; engineering planning by Corps of Engineers (Civil Works).



NATIONAL FOREST MAPS

FOREST SERIES MAPS
1:126,720-SCALE

(1 inch=2 miles)

Available

To be mapped

Note: Nearly 40 maps are out-of-date. These cover about 126,000 square miles, an area equal to New Mexico.

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Figure 17

- o National Aeronautics and Space Administration -- Research, experimentation, and investigations in resource assessment and evaluation; environmental and ecological monitoring; disaster assessment; land use; change detection; and simulation of earth-orbiting satellite observations.

For the most part, these products are a major source of data for inventory, analysis, change detection, and monitoring. The products are of high value to the using agencies, and we found a relatively effective degree of coordination among the agencies in exchanging photographic data to reduce duplication. DOD aircraft photographs can be made available to civilian agencies, but generally they are obtained for strictly military requirements, and their use by the civilian community is the exception rather than the rule. NASA photographs are mostly furnished to investigators for a particular purpose, and the fact of their acquisition is not widely communicated nor can they be easily obtained by Federal agencies for their programs.

Of the $12.4 million spent for Other Photo Products, approximately $5 million is spent for imagery collection. Considerable savings can be achieved by better coordination and integration of imagery collection and exploitation.

THEMATIC AND OTHER SPECIAL-PURPOSE MAPPING

Thematic and other special-purpose maps are used by many Federal agencies in carrying out operational programs. These maps are discussed under seven categories: soils, geologic and hydrologic, flood insurance, cadastral, recreation, local project, and miscellaneous.

Thematic maps emphasize a single theme annotated or printed on a base map containing fundamental information for reference. The thematic data are compiled for the purpose of inventory or scientific analysis of resources (soils, geology, hydrology); display of social, statistical, or political information; outdoor recreation opportunities and developments; land-use classification; or inventory of road systems.

We directed our attention primarily to those systematic programs that transcend local or regional areas of interest. Local-project and miscellaneous maps are nonsystematic and generally local in subject and application. These are separately discussed.

Soil Maps ($3.6 million)

Soil maps are a graphic presentation of soil surveys. The mission of the Soil Conservation Service's soil-survey program ($21.4 million) is to assist in conservation, development, and productive use of the Nation's soil, water, and related resources. Soil surveys are made to determine soil-use potentials and conservation treatment needs, and results are published with interpretations useful to cooperators, Federal agencies, and state and local governments. The work is carried out in cooperation with state agricultural experimental stations and other state and Federal agencies.

Preparation of soil maps requires the joint efforts of soil scientists and cartographers. The cartographers obtain aerial photographs and make photomosaics for the soil scientists, who conduct detailed field examinations of the soils, classifying them and delineating them by type on the mosaics. Completed field-survey sheets and draft texts are then forwarded to Washington, where cartographers compile

the soils data on a photoimage base of new photographs. Soil survey books containing the maps and text are prepared, usually in county units, and are printed in-house or by the Government Printing Office.

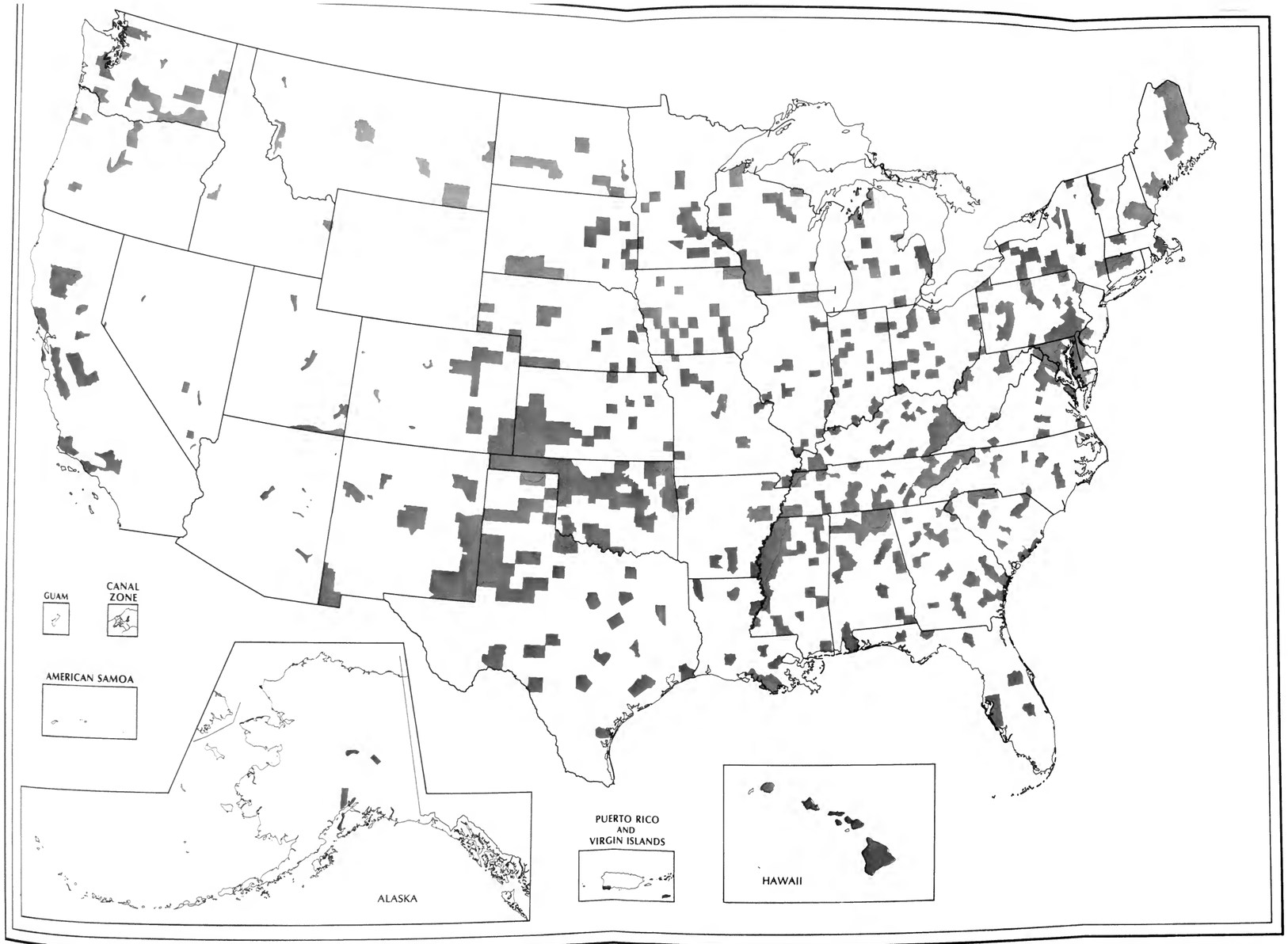
Between 1934 and the present, surveys for 17 percent of the country have been completed and published (fig. 18). SCS plans to complete and publish soil surveys for most of the country and update them on a 20- to 25-year cycle.

SCS is developing techniques for digitizing soils information for a computer data base and for automating some of the cartographic procedures necessary to produce finished soils maps. We were not impressed with these plans because the accuracy of the basic data being digitized is reduced substantially by the inherent inaccuracy of the original photo base. Because of the inaccuracy, the data will not correlate readily with spatial information produced by other agencies spending Federal funds. This is a prime example of the way a well-intentioned, single-purpose effort can be wasteful.

We recommend that the production process for soils maps be improved by aggressive application of advanced cartographic technology. Following this improvement, the plans for digitization should proceed in a way that will assure that the digital data are compatible with and to the same accuracy standards as other spatial data. We further recommend that the soils survey cartographic and publication effort be transferred to the new central mapping agency.

Geologic and Hydrologic Maps ($2.3 million)

Geologic and hydrologic maps graphically portray results of the geologic and hydrologic investigations. GS conducts systematic surveys, investigations, and research throughout the U.S. and its outlying areas of sovereignty. These scientific studies assess and appraise the distribution and quantity of mineral, water, and land resources. The published results of these studies generally include geologic or hydrologic maps.



NATIONAL SOIL SURVEY PROGRAM

(At scales of
1:15,840
1:20,000
1:24,000
and 1:31,680)

Published soil surveys (485,000 sq. miles)

Note: The Soil Conservation Service, USDA, plans to publish soil surveys on an additional 2,400,000 square miles of the United States and Puerto Rico.

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Figure 18

Geologic maps, the most common basic research products, show the distribution of rock and earth materials, with both surface and subsurface structural relationships. Geologic data and analysis are a necessary precursor for the appraisal of mineral, fuel, and land resources. Hydrologic maps, in part derived from topographic and geologic maps, show the distribution and quality of surface and ground water and thus provide the data necessary for proper appraisal of water resources.

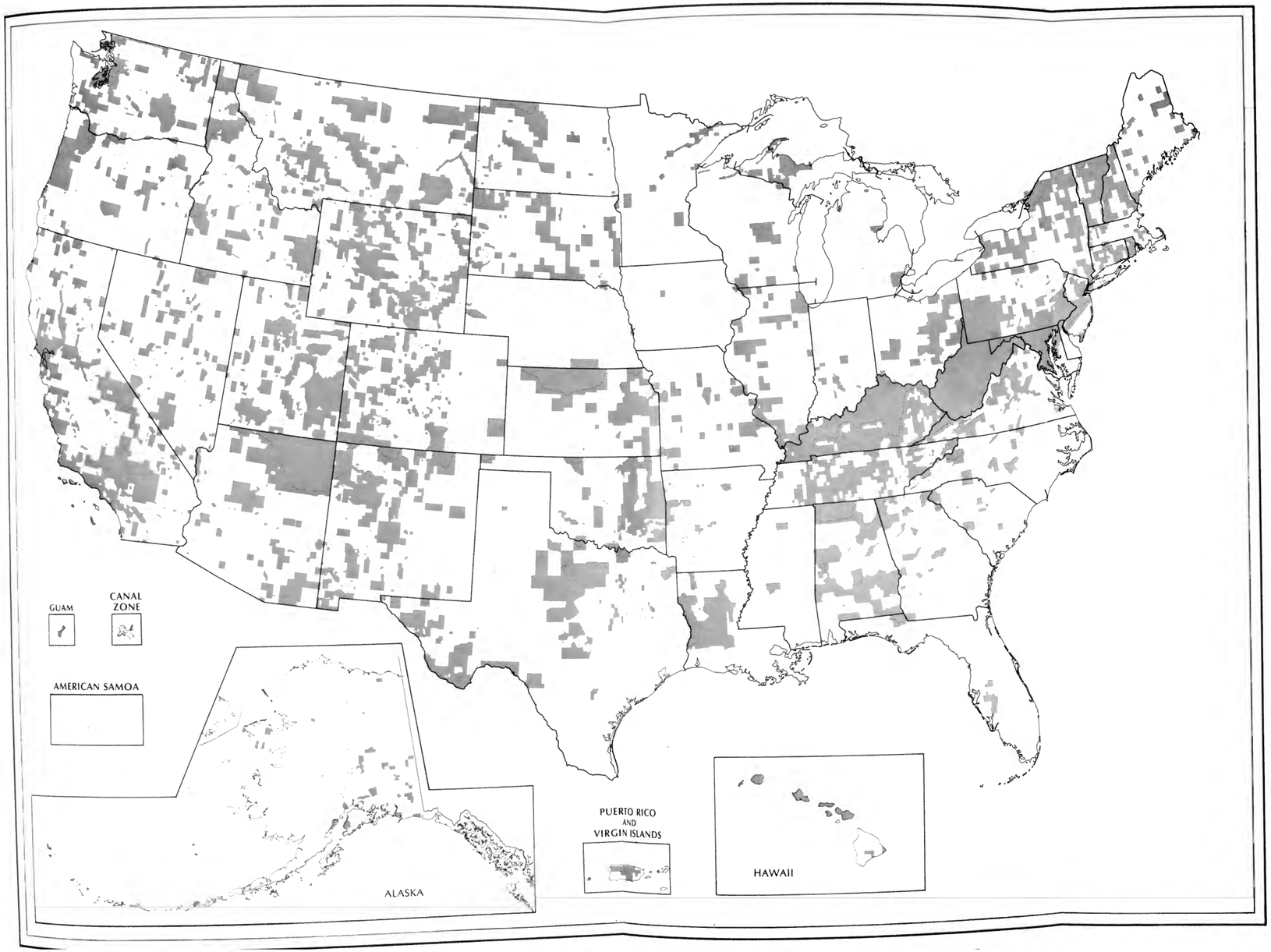
Geologic and hydrologic maps are used by numerous Federal, regional, state, and local agencies, universities and other research groups, and commercial interests, particularly oil and mining companies. Representative specific uses for these maps include: (1) identifying location, extent, and extraction potential of metallic and nonmetallic ore deposits, mineral fuels, and other energy resources; (2) evaluating engineering sites and construction materials; (3) locating natural geologic and hydrologic hazards; and (4) appraising land-use capabilities and potential ground-water supplies.

GS produces a variety of geologic and hydrologic maps at varying scales. However, only Geologic Quadrangle maps are produced for a significant portion of the U.S. (fig. 19). They portray basic geologic characteristics of an area on standard topographic bases at scales ranging from 1:24,000 to 1:63,360.

We recommend that the cartographic and reproduction effort necessary to prepare and publish geologic and hydrologic maps be transferred to the new agency to make most effective use of like skills and state-of-the-art technology.

Flood Insurance Maps ($2.0 million)

Derived from existing maps, flood insurance maps are prepared for coastal and inland flood-risk areas. HUD finances the maps as a part of its requirements for administering the National Flood Insurance Act of 1968. In FY 1972, approximately $2.0 million was expended. Of this amount, $140,000 was spent for in-house products, including $45,000 for printing. Some $1.7 million was spent through contracts for mapping by other Federal agencies, and the remainder was spent under contract with commercial firms.



GEOLOGIC MAPS

(At scales of
1:24,000 and 1:62,500)

Areas for which maps showing basic geologic characteristics are available.

Figure 19

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Scales range from 1 inch equals 600 feet to 1 inch equals 4,000 feet. Contractor-developed information is added to existing base maps. The major users of the maps are public policymakers, urban planners, developers, the general public, and the flood insurance industry.

We conclude that flood insurance mapping can be made most effective if it is centrally managed, and production is geared to requirements established by the Federal Insurance Administration.

We recommend that flood insurance mapping be accomplished by the new agency, and that standards and specifications be developed in accordance with HUD requirements.

Cadastral Maps ($4.6 million)

One type of cadastral map is the graphic record or plat of cadastral surveys. These plats and the notes from which they are prepared become permanent legal records. Cadastral surveyors prepare the plats and are responsible for their authenticity. The plats are prepared to scale (usually 1:31,680, 1 in. to 1/2 mile) and made available to all interested parties. Much of this work is done by BLM, which is responsible for the systematic cadastral surveying and platting of the public lands.

Land-status maps are another form of cadastral maps. They graphically show ownership and restrictions and the status of properties in the vicinity of Federal lands. Continually changing land status and management activity near boundaries between Federal and non-Federal lands require FS, BLM, and others to update these maps frequently. Titles and encumbrances must be kept current and in the proper spatial relationship with the terrain and natural resources. This information is usually plotted on an overlay to an existing base map. The dynamic nature of this activity lends itself best to continued accomplishment by the land-management agencies.

Very-large-scale, detailed cadastral plats are prepared by many agencies (Corps of Engineers -- land acquisition for flood control and navigation projects; NPS, BSFW, and FS -- road rights of way; HUD -- urban renewal). The plats of public-works projects are prepared for and filed with project and land-transfer records.

We recommend that the task of preparing official cadastral plats for the national cadastral reference network be identified as a responsibility of the new agency against requirements of the land-management agencies. The new agency should also develop standards and specifications for the Federal cadastral maps and for data input to them.

Recreation Folders ($0.5 million)

A primary mission of the Forest Service is to manage public recreation within the National Forests. Recreation Folder maps are provided free of charge to forest visitors to insure their safety, to guide them within the Forests, and to provide them with a brief conservation message. About 3,421,000 copies of these maps were printed and distributed in 1972 at a cost of $363,000.

Because of the primitive environment and the many restrictions on land use (wilderness areas, motorized vehicle restrictions, fire closures), more detailed information is needed than is usually available on small-scale general-purpose maps. For most Forest visitors, standard quadrangle maps cover too small an area and are too detailed to be of practical use. The Recreation Folders are produced at scales of 1/4 inch to 1/2 inch to the mile. They are cartographically derived from the 1/2-inch-to-the-mile Forest Series maps. Present coverage approaches 100 percent, although 75 percent of the published folders are inadequate. Cultural detail is insufficient, and format is inconsistent. Updating and standardization of the series is planned.

We recommend that the new agency address the task of furnishing map products like the Recreation Folders for all Federal agencies who require such products, working in concert with the agencies on format, standards, design, and production schedule.

Local-Project Maps ($17.0 million)

Local-project maps are very-large-scale maps (1 in. = 50 ft. to 500 ft.) which provide basic terrain information for planning, analysis, construction, and monitoring of engineering projects. They are used internally by a program agency to support design and construction of transportation and utility systems, community development, and utility

and zoning regulations. In the majority of cases, the maps have served their purpose when the project is completed. They usually cover relatively small areas, and, even at major construction sites, they no longer represent the topographic conditions after construction and are important only as a record of past conditions. Other local-project maps are used for zoning, flood control, sanitation, or other regulatory purposes and are updated as funds permit to show new developments within the projects.

Miscellaneous Maps ($8.6 million)

Many agencies produce miscellaneous maps to provide graphic data in direct support of their programs and research investigations. The products include photomaps, transparent overlays, and annotated base maps for watershed, conservation, and land-development projects; adminstrative maps, seismic-risk maps and seismicity charts; and maps of congressional districts, traffic flow, and land use.

Local-project and miscellaneous maps are produced by widely diverse, nonsystematic efforts by Federal agencies and are usually local in nature, single-purpose, nonrepetitive, and variable in format and standard. They are sometimes derived from available base maps, though there is little evidence of assiduous effort to avoid waste and duplication. Some of the products have application for other uses, but their existence is not widely known. Some of these activities are fit candidates for coordination or performance by a national mapping agency, but most are not.

We recommend that the new agency establish clear criteria for local-project and miscellaneous maps, including scale, area, accuracy, and project cost, and coordinate the efforts to produce them. The new agency will also actively service agencies with mapping requirements by furnishing an existing product, modifying a product to suit the need, or assisting the agency in effecting a responsive contract.

AERONAUTICAL CHARTING

Program Description

Simply stated, the objective of the Federal Aeronautical Charting Program is to provide timely, accurate information necessary for safe navigation by both civil and military aircraft. Information on the National Airspace is dynamic and must be kept current and fully explained. A set of aeronautical charting products has been developed as the mechanism to communicate essential airspace data to controllers and navigators (military and civilian). Consequently, these charting products must be updated and reissued as new facilities, procedures, ground or airborne devices, rules, or regulations are introduced.

As shown in table 5, $16,539,000 and 822 man-years were spent in FY 1972 by three Departments in domestic chart production. The Department of Commerce, through NOAA, and the Department of Defense, through DMA, are the only Federal producers of aeronautical charts and related data; the Department of Transportation, through FAA, furnishes requirements, specifications, and airspace information used in chart preparation based in part on advice received from civil and military airspace users. FAA also provides funds to NOAA for the development and first-year production of new or revised charts or chart series and reimburses NOAA for special graphic materials used by FAA to operate the National Airspace System (NAS).

Prior to 1965, there were highly visible duplication and overlap between the aeronautical charting programs of the Departments of Defense and Commerce. As a result of strong Bureau of the Budget and Congressional pressures, an Interagency Air Cartographic Committee (IACC) was established to coordinate FAA, DOD, and DOC production of air cartographic materials and to insure their production at minimum cost and with no unnecessary duplication. Under IACC agreement, DOC is responsible for fulfilling civil and joint civil/military domestic requirements and civil requirements outside the domestic U. S., whereas DOD is responsible for fulfilling military requirements whether domestic or worldwide.

Products

The following three basic types of products meeting joint-use IACC-approved specifications are published currently: visual charts, instrument charts, and special charts. See table 6.

Visual navigation charts are produced to meet the specialized need of the pilot flying under visual flight rules. They contain a topographic base designed to emphasize important natural and man-made features together with symbols for airways, airports, radio facilities, hazards, restricted areas, and cartographic representation of rules and regulations. NOAA produces the basic visual chart series, and DMA uses NOAA reproducible copies to prepare separate military editions and other special charts for specific military requirements.

Instrument navigation charts are the means by which data depicting the National Airspace, navigation aids, communication facilities, and air traffic control procedures are made available to pilots flying under instrument flight rules. Instrument charts are reissued normally on a 28-day cycle, corresponding to the cycle used by FAA in making changes to the National Airspace System. FAA studies indicate that this cycle is optimum economically and mechanically and therefore should not be changed even though lengthening the cycle would decrease the cost of the supporting charting program. NOAA and DMA both produce instrument charts, although NOAA reproducibles are used by DMA whenever possible.

NOAA also produces special charts and related products, including airport obstruction, aircraft position, controller, and video charts. DMA also produces other special tactical charts for DOD operational use.

Printing and Distribution

Printing and distribution of aeronautical charts and related products for civilian and military domestic users cost $4.6 million in FY 1972, of which $2.8 million was funded by DMA and $1.8 by NOAA. Overall, DMA produces a larger volume of domestic charts than NOAA, in part due to military packaging procedures and the method of distribution and product use.

TABLE 6

Production, Costs and Use of Aeronautical Charts by Type

Major Aeronautical Chart Products	Producer	Coverage	Update Cycle	FY 72 - $ In Thousands	Users % Federal	Users % Non-Federal
Visual Charts						
Sectional Charts (1:500,000)	NOAA	Ct. U.S.[1]	6 months	$1,981	32*	68
World Aeronautical Charts (1:1,000,000)	NOAA	Cn. U.S.[2]	1 year	376	20*	80
Terminal Area (1:125,000)	NOAA	U.S.	6 months	158	58	42
Medium & Small Scale Charts	DMA	U.S.	Unscheduled	782	100	-
Instrument Charts						
Radio Facility (Low)	NOAA	Ct. U.S.	4 weeks	641	28*	72
Radio Facility (Low)	DMA	Ct. U.S.	4 weeks	601	100	-
Radio Facility (High)	NOAA	Ct. U.S.	4 weeks	52	67*	33
Radio Facility (High)	DMA	Ct. U.S.	4 weeks	53	100	-
Radio Facility (Low)	NOAA	Alaska	4 weeks	55	96	4
Radio Facility (High)	NOAA	Alaska	4 weeks	32	98	2
Area Navigation Charts	NOAA	Ct. U.S.	4 weeks	99	85	15
Area Charts	NOAA	Ct. U.S.	4 weeks	54	18*	82
Chart Supplements	NOAA	Alaska, Pacific	4 weeks	146	96	4
IAPC	NOAA	U.S.	Unscheduled	1,569	14*	86
IAPC	DMA	U.S.	Unscheduled	863	100	-
SID	NOAA	U.S.	8 weeks	128	63	37
SID	DMA	U.S.	8 weeks	27	100	-
Standard Terminal Arrival	NOAA	Ct. U.S.	8 weeks	20	---New---	
Special Charts and Related Products						
Airport Obstruction	NOAA	U.S.	Unscheduled	1,170	68	32
Aircraft Position	NOAA	Overseas Operation	6 months	184	11	89
Controller Charts (FAA)	NOAA	U.S.	4 weeks	725	100	-
Video Charts (FAA)	NOAA	U.S.	4 months	282	100	-

[1]Conterminous U.S. (48 States).

[2]Continental U.S. (49 States)

*Military editions are produced by DMA from NOAA reproducibles with special military information added to meet military requirements.

NOAA's aeronautical chart printing operation is accomplished in-house. It is integrated with nautical chart production in such a manner as to meet the firm cyclic requirement and at the same time eliminate printing peaks and valleys. DMA printing is accomplished by both in-house effort and contractual services, the bulk of which is contracted.

The DMA-produced charts are distributed directly from the printing contractor and the St. Louis facility to the various military commands, while NOAA's products are distributed from the Riverdale, Md., facility which also handles the nautical chart products. Most of the instrument charts are distributed to civil users through subscription (130,000 monthly). In addition, some 1,350 aeronautical chart agents throughout the U. S. provide a sales outlet basically for the NOAA-produced visual charts.

Production and Funding Responsibilities

During our study we sought answers to the following major questions:

- In view of the substantial non-Federal production of aeronautical charts and related products, should the Federal Government continue its production activities?
- Should domestic charts be produced by both military and civilian organizations?
- Should the funding of aeronautical charts be the responsibility of FAA or the producing agency?

Our conclusions and recommendations on these questions were derived after thorough examination of user requirements, production techniques, and funding procedures.

Federal vs. Non-Federal Production. -- There are a number of private producers such as Jeppesen, Skyprints, and Flight Guide, who compile aeronautical charts from government airspace information and sell their products at prices competitive to those charged by the Federal Government. Many states also publish some form of aeronautical

charting information, such as visual charts, enroute charts, airport directories, and the like, most of which are free. The privately produced charts are tailored for specific clientele, are not bound by government specifications, and, in the case of Jeppesen, the largest private producer, are copyrighted. In addition, as in the case of Jeppesen, whose products are designed for major airline companies, other types of products and services (not furnished by the Government) are supplied along with the aeronautical chart information as a package deal. For example, the Jeppesen Company provides the commercial airlines a tailored hijack kit.

Although we endorse the general principle that non-Federal production of MC&G products similar to Federal products should be encouraged, this in no way negates Federal responsibility to produce official products, particularly those relating to safety of the National Airspace. Federal production of National Airspace System (NAS) regulations and information interpreted through charts is the vehicle by which the Government manages and assures NAS safety. Some have argued that Federal chart production is creating unfair competition with commercial companies. We do not subscribe to that argument for the following reasons:

- Commercial cartographic concerns have no capability, nor do they indicate a willingness to develop one, to collect, digest, and uniquely format airspace data independent of government operations (i.e., provide all airspace information from concept to concrete).

- Commercial cartographic concerns would not be interested in maintaining a full set of products on a precise cycle for all types of users (including the private pilot), covering all geographic areas, unless these products returned a profit. Although some commercially produced products are timely, we believe they are kept up to date so they can compete with Federal products and would not be as responsive if they were the sole source. Airspace changes will continue to be planned and effected whether or not commercial products are available.

We recommend, therefore, that the Federal Government continue to produce the official aeronautical charts for National Airspace operations and safety.

Civilian vs. Military Chart Production. -- As previously stated, NOAA and DMA publish and distribute aeronautical chart products and expend essentially the same funds. The cartographic functions of DMA for domestic areas are limited to producing special military charts and applying military information to NOAA-produced reproducible materials. Although the DMA cartographic effort is small, its large expenditure is due to the volume of copies produced and its packaging procedures. NOAA uses a looseleaf format for instrument approach procedure charts and relies on the user to insert changes, whereas DMA reproduces the entire publication in a bound volume each 28 days. According to DOD studies, this costly DMA packaging provides additional safety and is less expensive overall than requiring military flight-operations personnel to continually update a looseleaf system. After an intensive review of DMA and NOAA operations, we believe little if any efficiency or overall savings could now be gained by combining the two operations, especially since the DMA responsibility on the domestic side is a very small part of its overall charting operations.

We therefore recommend no immediate change in the present production responsibility of domestic aeronautical charts.

There are, however, developments underway, such as automated production procedures, revised product packaging, changes in printing capacities, and new products, any one of which may warrant future consolidation. Automated production of some aeronautical charting products is rapidly becoming essential due to ever-increasing quantities of airspace data being added and revised, complexity of the airspace system, personnel required to keep up with cyclic workload, and, probably most important, the safety aspects of these products. Recent NOAA studies have demonstrated that instrument charts can be produced efficiently using automated techniques.

Since automated procedures apply to worldwide as well as to domestic charts, we recommend DMA and NOAA jointly develop and implement automated techniques for production of aeronautical

instrument charts and data. We estimate that an investment of $3 million total over the next 5 years would automate civilian production. Compared to present manual production, an automated system would yield timelier and safer products and save approximately $500,000 annually in civilian charting. It would provide even greater savings when combined with the military charting program for foreign areas.

Civilian Agency Funding Responsibility. -- As earlier described, aeronautical charting is accomplished through distinct divisions of labor. FAA determines the operational requirements, priorities, coverage, content, and standards for civilian aeronautical charts and related products and services. In turn, NOAA supports and assists FAA in the production and distribution. Increased funds required to produce and maintain the standardized products have been budgeted in recent years by both NOAA and FAA, with FAA's production funds provided to NOAA on a reimbursable basis without companion personnel slots. FAA also budgets for start-up and first-year costs of new or revised products as well as for production of special products for FAA's internal use. We have concluded that the present split funding of the standardized products, contingent on year-to-year agency resource constraints, is cumbersome and inefficient and should not continue.

We believe that the producing agency should be funded for the production of standardized aeronautical charts, for the following reasons (even though we recognize that in years immediately following extensive new requirements the program increases may, by necessity, become "sacred cows"):

- A single budget containing the basic program would be presented to OMB and Congress.

- Central management could maintain a more stable and efficient operation, with only start-up costs of new products and costs of special FAA internal-use products funded by FAA.

- Personnel slots could be adjusted consistently with program authorizations. (Transfer of slots is normally not allowed by OMB with reimbursable funds.)

Consistent with our proposed policy on other standard MC&G products, we recommend that a central MC&G agency be funded for the production of basic, standardized aeronautical charting products. To implement this recommendation, we believe a one-shot base to base transfer of FAA's funds for these products should be made to the new agency.

MARINE MAPPING AND CHARTING AND RELATED SURVEYS

In FY 1972, 17 Federal agencies within four departments and three independent agencies spent $219,560,000 and 5,371 man-years on marine mapping, charting, and related surveys. A major part of these funds, $103 million, was spent on surveys related to mapping and charting, through common dependence on ship operations, technology and methodology, and the same resource pool. As shown in table 7, we identified two categories of marine mapping and charting activities -- systematic mapping and charting (i.e., nautical charting and bathymetric and geophysical mapping) and scientific and engineering surveys (i.e., hydrographic, bathymetric, and geophysical). FY 1972 resources for the categories were $50,387,000 and $66,582,000 respectively.

Marine activities are discussed in four major sections as follows:

- Nautical Charting and Hydrographic Surveys.
- Bathymetric Surveys and Mapping.
- Geophysical/Geological Surveys and Mapping.
- Platform-Related Survey Activity.

Conclusions and recommendations follow the appropriate category or categories to which they pertain.

NAUTICAL CHARTING AND HYDROGRAPHIC SURVEYS

Nautical charts and related information are produced to satisfy marine navigational needs and to contribute to national goals, such as managing ocean resources, developing basic science, and improving national defense. The set of navigational products now being systematically produced by the Federal Government require activity in data collection and reduction, compilation, printing, and distribution. The products include conventional and special-purpose nautical charts, tide and current tables, tidal current charts, special publications for navigators, and timely notices to mariners. These products become quickly outdated because of natural changes caused by wind, tide, earthquakes, and subsidence and because of manmade changes, such as opening new ports, straightening rivers, dredging channels, building docks, bridges, breakwaters, and pipelines, and adding or moving aids to navigation. Continual monitoring of changes and updating of products, therefore, are required for safe and efficient marine navigation.

The Department of Commerce and the Department of Defense have the primary responsibility for nautical charting. Within DOD, the Defense Mapping Agency provides navigational information needed to operate DOD ships and the Merchant Marine in foreign areas.

DOD's domestic charting responsibility was reduced when the Lake Survey was transferred from the Corps of Engineers (CE) to NOAA in 1970. CE, however, is authorized to publish navigational information covering certain inland waters of the Nation. Policies and procedures have been developed for continuous coordination between CE and NOAA to avoid duplication.

NOAA conducts surveys and prepares nautical charts and related information of the harbors and coastal and offshore waters of the U.S. and outlying areas of sovereignty. Although the hydrographic data are collected by NOAA's National Ocean Survey (NOS), the Coast Guard (CG) regularly furnishes information on aids to navigation (buoys, lighthouses) and provides data on bridge clearances, electronic navigation systems, and the like; and the Corps of Engineers supplies data on controlling depths of navigable rivers and channels. The U.S. Power Squadrons and the U.S. Coast Guard Auxiliary report approximately 5,000 essential change items annually which are used in chart maintenance.

TABLE 7

FEDERAL MARINE MAPPING, CHARTING AND SURVEYING

(FY 1972 Expenditures in Thousands of Dollars.
Resources Shown in () Contracted to Other Agencies.)

Agency	Systematic Mapping and Charting								Scientific & Engineering Surveys								Total		Platform Related Surveys	
	Nautical Charting		Bathymetric Mapping		Geophysical Mapping		Subtotal		Hydrographic Surveys		Bathymetric Surveys		Geophysical Surveys		Subtotal				Oceanographic Surveys	
	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY
DEPARTMENT OF DEFENSE																				
Defense Mapping Agency	- (342)	-	-	-	-	-	- (342)	-	-	-	-	-	-	-	-	-	- (342)	-	-	-
Office of Naval Research	-	-	-	-	-	-	-	-	-	-	-	-	21,700	50	21,700	50	21,700	50	32,300	380
Navy Operations	-	-	12,799	197	1,888	18	14,687	215	-	-	11,865	84	2,500	20	14,365	104	29,052	319	8,549	88
Corps of Engineers, U. S. Army	37	1	-	-	-	-	37	1	6,662	395	-	-	-	-	6,662	395	6,699	396	-	-
Mississippi River Commission, U. S. Army	15	1	-	-	-	-	15	1	560	34	-	-	-	-	560	34	575	35	-	-
TOTAL - DEFENSE	52 (342)	2	12,799	197	1,888	18	14,739 (342)	217	7,222	429	11,865	84	24,200	70	43,287	583	58,026 (342)	800	40,849	468
DEPARTMENT OF THE INTERIOR																				
Geologic Division, Geological Survey (GS)	-	-	-	-	-	-	-	-	-	-	-	-	3,290	59	3,290	59	3,290	59	-	-
Conservation Division, GS	-	-	-	-	-	-	-	-	-	-	-	-	3,243	150	3,243	150	3,243	150	-	-
Bureau of Reclamation	-	-	-	-	-	-	-	-	162	12	-	-	-	-	162	12	162	12	-	-
TOTAL - INTERIOR									162	12			6,533	209	6,695	221	6,695	221		
DEPARTMENT OF COMMERCE																				
National Ocean Survey, National Oceanic and Atmospheric Administration (NOAA)	20,635	1,012	906	46	1,950	90	23,491	1,148	-	-	-	-	-	-	-	-	23,491	1,148	-	-
Environmental Data Service, NOAA	-	-	-	-	125	5	125	5	-	-	-	-	-	-	-	-	125	5	-	-
Environmental Research Laboratories, NOAA	-	-	-	-	-	-	-	-	-	-	-	-	3,377	166	3,377	166	3,377	166	3,434	137
National Marine Fisheries Service, NOAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21,285	1,091
TOTAL - COMMERCE	20,635	1,012	906	46	2,075	95	23,616	1,153					3,377	166	3,377	166	26,993	1,319	24,719	1,228
DEPARTMENT OF TRANSPORTATION																				
U. S. Coast Guard	1,856	181	2,350	241	-	-	4,206	422	-	-	-	-	550	53	550	53	4,756	475	7,223	853
INDEPENDENT AGENCIES																				
Atomic Energy Commission	-	-	-	-	-	-	-	-	-	-	-	-	90	1	90	1	90	1	-	-
National Science Foundation	-	-	-	-	7,800	-	7,800	-	-	-	-	-	12,500	-	12,500	-	20,300	-	29,800	-
Tennessee Valley Authority	26	1	-	-	-	-	26	1	83	5	-	-	-	-	83	5	109	6	-	-
TOTAL - INDEPENDENT AGENCIES	26	1			7,800		7,826	1	83	5			12,590	1	12,673	6	20,499	7	29,800	
TOTAL	22,569 (342)	1,196	16,055	484	11,763	113	50,387 (342)	1,793	7,467	446	11,865	84	47,250	499	66,582	1,029	116,969 (342)	2,822	102,591	2,549

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The NOAA/NOS nautical charting program now provides some 820 charts and other information needed for safe and efficient navigation. Depending on how many and what kinds of changes occur, the updating interval of these products ranges from 6 months to 4 years. The five basic types of charts and the users by category in percent are:

Type	Scale Range	Federal	Maritime	General Public
Sailing	1:600,000 and smaller	62%	13%	25%
General	1:100,000 to 1:600,000	50%	17%	33%
Coastal	1:50,000 to 1:100,000	40%	20%	40%
Harbor	1:50,000 and larger	60%	13%	27%
Small Craft	1:80,000 to 1:15,000	12%	6%	82%

The Federal users are primarily the Navy and the Coast Guard. Since their demand is critical, they have considerable influence on content and frequency of updating. In fact, if their demand is unmet, these primary users report that they would be forced to produce pertinent charts themselves.

Sailing charts are used for offshore navigation between distant coastal ports and for approaching the coast from the open sea. They show offshore water depths and the more important lights, outer buoys, and natural landmarks that are visible from considerable distance at sea. Area coverage is complete, and updating on a 1- to 4-year basis is being accomplished.

General charts are designed for coastal navigation well offshore but still requiring reference to landmarks, lights, buoys, and characteristic water depths. Area coverage of this chart series is about 95 percent complete, and the updating interval is governed by the rate of change in each particular area, which ranges from 6 months to 4 years. Major inadequacies are the incomplete coverage of Alaska waters and the lack of submerged oil field obstructions delineated on Gulf of Mexico charts.

Coastal charts are used for close coastal navigation inside outlying reefs and shoals, in the entrances of bays and harbors of considerable size, and in the larger inland waterways. Area coverage is

about 80 percent complete, and the updating interval is generally the same as that of general charts. Current unmet requirements include modern surveys to describe better the critical water depths in many areas and faster and more effective updating to provide more frequent and exact navigation information on charts.

Harbor charts provide information for safe navigation in harbors and smaller waterways and identify restricted waters and anchorages. The present updating interval ranges from 6 months to 4 years. Although area coverage is considered 80 percent complete, additional coverage is required for new harbors, and larger scale coverage is needed in some harbors whose use has increased so that existing small-scale coverage is inadequate. Unmet requirements include more complete and timely information on channels, frequent updating of critical navigational information, and additional area coverage of harbors where marine transportation is increasing rapidly, particularly in Alaska.

Small-craft charts are designed for operators of small boats in waters heavily congested by recreational boaters and for operators of all vessels (including deep-draft) in areas for which the route-type, folded format is well suited for navigation, (i.e., rivers and intracoastal waterways). Where this chart satisfies harbor chart requirements, no harbor chart is provided. User requirements are generally being met in areas where modern surveys have been accomplished and published.

Critical navigational information obtained during a NOS survey is reported to the users through the Notices to Mariners and is applied on the next edition of the chart. Due to the manual data-handling methods presently employed, however, the complete new survey information is not being applied to the published chart for up to 5 years, thereby delaying some major benefits of the new survey. NOS is in the process of implementing automated procedures which are expected to reduce this data-handling time to approximately 6 months.

Of foremost importance to the preparation of a series of coastal and inland charts is a basic, integrated geodetic network, which provides a single horizontal control datum for relating the charts to the surface of the earth in position, scale, and orientation.

Similarly, a vertical control datum (tidal) is required to establish a consistent reference for hydrographic data.

The major activities required in the production of marine charts include: (1) photogrammetric support services, involving analytic extension of control, delineation of shorelines and other planimetric features, and plotting photoidentifiable navigation aids and hazards; (2) tides and tidal current surveys, involving collection, reduction, and interpretation of data obtained through an extensive network of control tide stations; (3) cartographic compilation; (4) reproduction and distribution facilities, which are operated by and are an integral part of the NOS aeronautical charting activity (distribution is also accomplished through some 720 authorized sales agents from independent marinas, boatyards, and other marine suppliers); and (5) the basic hydrographic surveys and data processing requiring survey vessels and shoreside support facilities.

Hydrographic Surveys

Most Federal Government activity in hydrographic surveys falls within three organizations -- the National Ocean Survey (NOS), the U.S. Naval Oceanographic Office (NAVOCEANO), and the U.S. Army Corps of Engineers (CE). Expenditures of funds and man-years in FY 1972 were as follows:

	Data Acquisition		Data Processing		Totals	
Agency	$K	MY	$K	MY	$K	MY
NOAA/NOS	8,898	484	1,767	107	10,665	591
NAVOCEANO	2,838	126	434	23	3,272	149
CE	6,238	361	607	53	6,845	414
Totals	17,974	971	2,808	183	20,782	1,154

The NAVOCEANO surveys are conducted in foreign areas, and these surveys as well as NOS surveys provide the basic source information for nautical charts, In the case of CE, hydrographic surveys are performed to acquire information essential to the maintenance of dredged navigation channels.

Since safety is the highest priority consideration in nautical chart compilation, hydrographic survey activity includes the precise location and delineation of all dangers to navigation (e.g., submerged rocks, reefs, ledges, and wrecks) within the survey area, the verification of the positions of existing fixed and floating aids to navigation as well as adjacent land features (landmarks) deemed to be of value to the mariner in determining ship position by visual observations, and verification of the location of the shoreline features of the adjacent land area.

The techniques used in acquiring hydrographic survey depth data vary somewhat depending upon the scale of the survey, the area to be surveyed, the type of bottom relief anticipated, and the type of equipment used. In general, however, the data are obtained by running parallel depth-sounding tracks over the survey area at a predetermined spacing.

The Corps of Engineers conducts three types of hydrographic surveys -- condition surveys, pre-dredging surveys, and post-dredging surveys. Condition surveys are performed on a regularly scheduled basis to detect shoaling and to plan for dredging operations. Information acquired during the pre- and post-dredging surveys is used to determine the quantity of material to be removed and whether or not specifications were achieved. Although the products are generally engineering drawings for in-house use, copies are provided to NOS, CG, and the Navy, and they serve as important input to the Coastal charting program.

Most of the hydrographic survey activity carried on by NOS is dependent on ships. The ships employed for this purpose vary from 163 feet in length, 760-ton displacement (WHITING), to 231 feet in length, 1,800-ton displacement (MT. MITCHELL). The ships were designed specifically for combined hydrographic survey operations and normally employ from two to four auxiliary sounding launches. A minor part of the overall NOS hydrographic survey effort is performed by shore-based survey operations, although recent studies have shown that most coastal areas along the Gulf of Mexico and the Atlantic should be surveyed by high-speed, shore-based operations in lieu of using expensive ships. Implementing properly designed shore-based systems, which would require initial capitalization, would improve efficiency and save millions of dollars in operational costs over the years.

Navy hydrographic (coastal) survey operations are supported by two 393-foot, 3,760-ton ships, the CHAUVENET and the HARKNESS, each capable of employing four sounding launches. Each ship also carries two helicopters for use in transporting personnel and equipment ashore in support of electronic positioning systems and geodetic survey operations.

Corps of Engineers hydrographic survey operations are conducted by shore-based operations. Each CE coastal district having hydrographic survey requirements operates one or more sounding launches and several boats.

Hydrographic survey data acquired by the Navy and NOS are either collected digitally or manually transformed to digital format immediately after collection. Most CE hydrographic survey operations, however, use manual recording and processing systems.

Basically, the hydrographic data collection and initial processing requirements of the Federal marine survey agencies are very similar. Costs associated with development and implementation of an integrated data-acquisition system are substantial -- $50,000 to $10,000,000 per installation, depending on the degree of sophistication. A considerable amount of redundancy in developing computer-based systems has occurred in the past between the Navy and NOAA. Each agency felt it had unique requirements (classification, degree of reliability, and level of funding available) for individual development. The Corps of Engineers is now experiencing similar problems in automated systems which can result in further duplication. Three CE districts have already purchased or leased three different systems, and virtually all the remaining 18 coastal districts are conducting independent research to develop systems for similar survey tasks.

We conclude that:

- The NOAA nautical charting program is a Federal responsibility and is necessary for marine navigation.

- The products are well conceived, without overkill, and are the vehicle for communicating information essential

for safe marine operations. Where problems of untimely updating exist, they can be corrected through accelerated use of automated techniques.

- Shore-based hydrographic surveys, supplementing ship operations, can significantly improve survey efficiency and effectiveness.

- Duplication in development of hydrographic data collection and processing systems exists within the several CE districts.

We recommend that nautical charting activities in U.S. coastal waters be accelerated to provide current navigational charts, especially for high-use and rapid-change areas by publishing more frequent editions reflecting the most recent navigational changes and the best available survey data. This increased production can be achieved through implementation of properly designed shore-based operations, where applicable, to supplement ship operations and through increased application of automated data-handling procedures. An investment of about $7.5 million ($4 million capital outlay) over a 3-year period would complete the automated data-handling system and provide three automated shore-based hydrographic field units equipped with computer-monitored data-acquisition systems. This investment would yield savings of about $1 million a year over costs of present data-handling procedures and cost avoidance of about $2 million a year for data collection. The cost avoidance would be realized through redeployment of existing ships to jobs and areas where they can operate more efficiently.

We recommend that the civilian nautical charting program manager be assigned immediate responsibility for coordinating the technical development and implementation of systems for hydrographic data collection and processing (including that of the Corps of Engineers, the Coast Guard, and the Navy) which can contribute data to the domestic nautical charting program. Such coordination would provide an integrated system for efficient use of all applicable hydrographic data for charting (whether or not initially collected for charting) and would prevent duplication in surveys, technical development, and procurement practices.

BATHYMETRIC SURVEYS AND MAPPING

Bathymetric surveys provide information for depicting ocean-bottom topography, whereas hydrographic surveys determine safe water depths and seek out hazards to navigation. Table 7 shows that $28 million and 568 man-years were spent in FY 1972 on bathymetric surveys by Navy, NOAA, and the Coast Guard.

The Coast Guard collects systematic bathymetric data in response to Navy requirements in specific ocean areas. These data are collected by ships enroute to and from ocean stations or on icebreaking missions, on an opportunity basis, and the data are added to the Navy bathymetric library for use in DOD programs.

The Navy bathymetric data file is the basis for preparation of operational charts, mostly classified. Unless downgraded and released, the classification prevents effective use of the charts or data by civilian agencies.

NOAA bathymetric surveys, in general, are rooted to requirements established by either the former Interagency Committee on Oceanography or the Commission on Marine Science, Engineering and Resources. Summarized, the requirements are: ". . . acquire knowledge of the sea floor features and processes that are essential to understanding ocean phenomena . . . [and] . . . assist industry and other Federal agencies in the assessment of the seabed and in planning its rational uses." While the collection of bathymetric data is always included in geophysical surveys, separate operations are sometimes planned to acquire bathymetric data only.

Within NOAA, the bathymetric data are collected as part of two programs -- SEAMAP and CONSHELF. The first is broad-brush mapping and description of selected deep-ocean areas, and the second is mapping and description of the U.S. Continental Shelf.

Requirements for both programs, supported in part by NSF reimbursable funding, are developed through annual user surveys (Federal agencies, State and local governments, mining and engineering interests, and local planning commissions).

Small-scale (1:1,000,000) bathymetric maps of the North Atlantic and Northeast Pacific (SEAMAP) are being provided to meet the requirements of scientific research and resource exploration. Since these are new products, information on distribution by user categories is not available.

Bathymetric maps of the U.S. Continental Shelf are produced at scales of 1:250,000 and 1:125,000. To date, only 22 percent of the area is mapped. About 50 percent of these maps are furnished to Federal agencies, and the remainder to State agencies, industry, and the general public. Some users want the remaining areas mapped at medium scale; others require more detailed information at the sacrifice of area coverage and timeliness.

As part of our review, we combined by areas the present and planned bathymetric surveys of Federal agencies merging both classified and unclassified operations. The resulting graphic showed apparent duplication only between the Navy and Coast Guard operations. As discussed earlier, however, the Coast Guard surveys were accomplished by ships of opportunity, supporting Navy requirements, and these data provide either new or amplifying information for Navy surveys.

Our conclusions on bathymetric surveys and mapping are as follows:

- Many Federally sponsored programs, military and civilian, rely heavily on bathymetric data.

- Most marine survey operations collect bathymetric data along with other geophysical data, and the

bathymetric data collection does not inhibit the operations or add significantly to their costs.

- Marine surveys supporting Navy worldwide charting responsibilities are dedicated to bathymetry and collect large amounts of classified data. The data, if made unclassified, theoretically could identify operating areas. The surveys, however, cover such large areas of the ocean that selected data can be made available for civilian use without jeopardizing national security.

We recommend a concerted effort be undertaken to make classified bathymetric data and charts held by DOD available to civilian agencies. The agencies should notify DOD of their requirements, urge declassification insofar as security allows, and explore the possibility of modifying DOD operations to serve both military and civilian requirements. Although we cannot estimate the benefits derivable from this recommendation, we believe they would outweigh the costs incurred several fold.

GEOPHYSICAL/GEOLOGICAL SURVEYS AND MAPPING

Within the context of this report, marine geophysical data pertain to numerical and graphic information acquired by remote-sensing methods for the purpose of describing subsurface variations in composition and structure of the earth's crust, mantle, and core under the oceans and Great Lakes. Marine geophysical surveys include the acquisition of magnetic, gravimetric, and seismic data and sufficient bathymetry for interpretation and presentation of geophysical findings. Geophysical and geological operations are distinguished on the basis of type of data collected.

A geological survey includes the acquisition of some numeric geophysical data in addition to physical data, such as geologic and geochemical data, and, for some purposes, physical, chemical, and biological oceanographic data. These surveys generally result in the preparation of a general-purpose geologic map and an interpretive report as final products.

Marine geophysical surveys are conducted for either mapping or problem-solving. Mapping data are acquired by running systematic lines at fixed spacing throughout the region to be mapped, whereas data for problem-solving are acquired by running concentrated lines in the locale of the problem, whether dimensionally large or small. A problem-solving survey involving a large area may be equivalent to a mapping survey.

Federal agencies conducting marine geophysical surveys are NOAA, GS, Navy, and NSF. The NSF and Navy also support the major part of academic marine geophysical surveys.

The principal agencies accomplishing marine geologic surveys are GS and the Marine Laboratories of NOAA. The Naval Oceanographic Office and some of the Naval Laboratories acquire and analyze geologic information for acoustic or engineering purposes, and NSF funds or manages several large programs, such as the Seabed Assessment Program of International Decade of Ocean Exploration (IDOE), the Deep-Sea Drilling Project, and parts of the Arctic and Antarctic programs that systematically acquire geologic information in those areas.

NOAA has the responsibility for geophysical mapping of the Great Lakes, coastal waters, and selected deep-ocean waters, conducts marine geophysical survey programs through NOS and ERL, and maintains geophysical data storage and retrieval in EDS.

As with the bathymetric surveys discussed earlier, NOAA's marine geophysical surveys are a fundamental part of the NOS CONSHELF and SEAMAP programs and respond to specific requirements and priorities established by annual user surveys. The geophysical products consist of gravity and magnetic maps (at the same scales as bathymetric maps) and seismic reflection profiles. Again, since the above are relatively new products, information on distribution by user categories is not available.

DOD's marine geophysical programs are carried on by NAVOCEANO, the Office of Naval Research (ONR), and the Naval Electronic Systems Command. The programs generally focus on efforts to understand acoustic properties of the ocean's water column and subbottom characteristics. Geophysical requirements are also tied to the need to know about the extent and location of gravity anomalies.

The Geological Survey conducts marine geophysical surveys and acquires marine geophysical data as a part of geologic investigations leading to better understanding of the Continental Shelf. The data are used in the management, conservation, and development of marine mineral resources and for geologic analysis. Within the Geological Survey, the Geologic Division makes scientific investigations and surveys and publishes maps and interpretative reports, and the Conservation Division uses proprietary geophysical information for analyses of Continental Shelf areas before lease sales and for management of leases.

The Coast Guard role in geophysical activity consists mainly in providing ships of opportunity for use by other agencies.

NSF sponsors basic and applied geophysical research through grants to academic institutions. The purpose of this research is

to provide information for better management of marine mineral exploration and to assist industry in planning more detailed investigations.

Expenditures in FY 1972 for marine geophysical/geological activities are shown below:

Agency	Data Acquisition[1] $K	Data Acquisition[1] MY	Data Reduction[2] $K	Data Reduction[2] MY	Totals[3] $K	Totals[3] MY
NOAA						
NOS	1,717	96	230	6	1,947	102
ERL	2,950	148	417	18	3,367	166
Navy						
Operations	27,406	210	1,646	109	29,052	319
Science*	14,500	20	7,200	30	21,700	50
CG	2,779	279	—	—	2,779	279
GS	3,201	55	3,332	154	6,533	209
NSF	14,300	-	6,000	-	20,300	-
Totals	66,853	808	18,825	317	85,678	1,125

* Navy labs. and instructional support.
1 Data acquisition includes purchase of data.
2 Data reduction includes editing, verification, evaluation, and analysis.
3 Totals include costs of bathymetric data acquisition and reduction as discussed in the previous sections.

Marine geological surveys are generally carried out in sequence of operations, or phases, that may require several years or longer to complete, as the planning for a later phase depends on synthesis and interpretation of earlier results, Inasmuch as geophysical and geological data are plotted on bathymetric base maps at suitable scales, adequate bathymetry must be obtained in the early phases. Accurate bathymetry, magnetic, and gravity maps enable the geologist to plan seismic traverse lines that most effectively will reveal subbottom structure. The results of a seismic reflection survey generally show areas of outcrop of hard rock ledges or areas where subbottom rock structures are covered by thin sediments. The geologist then uses this information to plan subsequent operations in which geologic samples of sediment and rock are collected by dredging or coring.

In any case, the kind of geologic problem under investigation determines the type of geophysical and geologic information collected, the positional accuracy needed, and the resolution or quality of the data. The necessary quality of the data, in turn, dictates the complexity of equipment and data processing, the size and stability of the platform, the maximum allowable ship speed, and the density (spacing) of the survey.

In analyzing marine geophysical/geological survey operations, we merged official (classified and unclassified) graphics showing all surveys accomplished and planned during 1972 through 1974. The synthesis showed no duplication of survey effort between Navy geophysical/geological surveys and those of the civilian agencies, although NSF/IDOE, NSF/Deep Sea Drilling Program, and NOAA's research tracklines at times traverse Navy working areas. This is not considered duplicative effort inasmuch as research lines running through a Navy-surveyed area usually investigate a well-defined problem within the area and extend well beyond the Navy survey limits. Nevertheless, if more Navy data were available to civilian agencies, better planning and better results would follow.

When analyzing the civilian surveys, we found that multiple survey coverage either exists in or is planned for several areas. We realize that budgetary cuts and reprogramming actions by NOAA have altered the 1973 and 1974 plans and eliminated some of the multiple

survey coverage indicated on our graphics. Even so, we believe some general tendencies concerning marine geophysical/geological surveys should be highlighted:

- The cart before the horse -- In several cases detailed geological investigations were found to precede generalized geophysical mapping, whereas geophysical surveys should precede geological investigations.

- Simultaneous surveys -- Two agencies conducting geophysical surveys in the same general area -- one seeking detailed data, the other, general area coverage. Although the surveys are not exactly deplicative, operationally they are inefficient.

- Uncoordinated priority shifts -- One agency shifts its survey priorities abruptly, affecting other agencies' operations. Thereby, overall inefficiency results, especially in geological investigations which are dependent on prior data.

We have concluded that DOD-classified bathymetric, magnetic, gravimetric, and acoustic data can be used beneficially by civilian marine organizations with substantial savings. These savings will appear in at least three ways: in program or project planning; in supplementing data already available or to be collected; and in eliminating duplicative survey projects. The release of such data in some unclassified form should be considered on a case-by-case basis taking into account the national interest from both military and civilian standpoints. DOD's present policy is to classify marine gravity data even though they are similar to data civilian agencies are freely publishing.

We recommend that the DOD agencies (Navy and DMA) be charged (1) to review all classification policies with the goal of declassifying as much data as possible and (2) to provide the necessary mechanism (personnel and facilities) to make classified marine survey data available for cleared civilian agency personnel. Correspondingly, Federal civilian authorities should clear need-to-know personnel to review and use these data holdings.

We believe that production of maps depicting the bathymetric and geophysical characteristics of the U.S. Continental Shelf at 1:250,000-scale is necessary to satisfy the needs of Federal agencies charged with marine resources management, coastal zone managmment, and related scientific studies and to provide information on legislative and international decisionmaking concerning ocean dumping, pollution, and Law of the Sea.

Although NOAA has recently terminated its marine geophysical survey and mapping program, we recommend that those types of products continue to be produced in a central MC&G organization using existing data to the maximum extent prior to planning any additional systematic survey effort. All data approaching mapping standards, especially DOD data and the industrial proprietary holdings, must be sought after diligently, analyzed, and used for mapping. We also recommend that data being acquired in support of problem-oriented research be made available for mapping and that the survey areas be modified where feasible to provide data critical to the mapping effort.

We recommend that the Interagency Committee on Marine Science and Engineering, established under the auspices of the Federal Council for Science and Technology to insure the planning and coordination of Federal activities in marine sciences and engineering and related matters, be charged with the responsibility to review in depth at least yearly, the Federal marine survey data-acquisition programs (both DOD and civilian agencies) regarding the efficient collection and use of geophysical/geological marine data. The Committee should make specific recommendations regarding effective and efficient use of classified and unclassified data and submit timely reports to the agencies involved and OMB for consideration in budgetary decisions.

PLATFORM RELATED SURVEY ACTIVITY

The collection of oceanographic data is generally conducted from ships similar to those used in hydrographic and geophysical survey operations. But, in contrast to the underway mode of collecting hydrographic and geophysical data, the majority of deep-ocean physical, chemical, and biological oceanographic data are collected while the platform is either lying-to or underway at very slow speeds.

Since most oceanographic data are temporal and spatial, they are collected on a recurring basis at stations or within areas that vary in size and number depending upon project requirements. While underway between oceanographic stations, the ship may measure and record: sea-surface temperature, salinity, and conductivity; bathymetry, gravity, and magentics; sea swell and wave heights; and meteorological data (wind, cloud cover, and temperature).

Physical and chemical (water column) oceanographic data are required for determination of the sound-velocity corrections applied to hydrographic and bathymetric survey depths. Physical oceanographic (water motion) observations provide the tide corrections required to adjust hydrographic and bathymetric depths to sea-level datum.

Marine biologists require physical and chemical oceanographic data to answer questions on sources and levels of nutrients in the sea. They use bathymetric data and water temperature to determine how fish species relate to both bottom topography and temperature. Data on water motion (tide and current), salinity, and turbidity are also needed in fish habitat studies.

There is a direct relationship between the physical, chemical, and biological oceanographic surveys described above and the Navy's acoustical surveys. To understand the how and why of sound transmission in the water and subbottom, it is necessary to know the water depth, the physical and chemical characteristics of the water column and subbottom, the amount and type of biological substance in the water, and the geographic position at which these data are collected. All of the above data are needed to provide an accurate

model of the ocean areas from which sound propagation, absorption, and generation can be predicted and evaluated in real time. These data are also used by scientists and engineers to develop acoustic system hardware that will perform effectively in the ocean either over a broad area or in a very discrete location.

The present and planned projects for marine surveys in which NOAA, CG, CE, and the academic institutions participate are part of the Federal and international ocean programs, Whether for purely scientific research or for specific engineering purposes, most of the data collected are used by Federal and State agencies. A major fraction of the Federally supported oceanographic survey activities is conducted by academic institutions. Each institution has representation and effects coordination through the University National Oceanographic Laboratories System (UNOLS). Large, prestigious commissions, such as the Stratton Commission and National Advisory Committee on Oceans and Atmosphere, have studied the requirements for and interrelationships of oceanographic surveys and have concluded that they serve national needs and should be continued.

The following table shows 1972 platform-related survey resources, most of which are not directly applicable to MC&G.

	Data Acquisition[1]		Data Processing[2]		Totals	
	$K	MY	$K	MY	$K	MY
NOAA						
NOS	587	19	723	30	1,310	49
ERL	2,654	119	780	18	3,434	137
NMFS	8,514	437	12,771	654	21,285	1,091
Navy						
Operations	7,749	44	800	44	8,549	88
Science*	21,500	120**	10,800	260**	32,300	380
CG	7,199	852	24	1	7,223	853
NSF	11,920	-	17,880	-	29,800	-
Totals	60,123	1,591	43,778	1,007	103,901	2,598

* Navy labs. and institutional support
** Navy lab. personnel only
1 Data acquisition includes purchase of data.
2 Data processing includes editing, verification, evaluation, and analysis.

Although oceanographic operations are generally not considered within the purview of MC&G, oceanography interfaces directly with marine mapping and charting programs not only in the use of like data (physical and chemical) but also in the use of similar data-collection techniques and platforms. Daily operating costs for marine survey and marine reserach ships range from several hundred dollars for small vessels (lengths of 75 to 100 ft.), through several thousands of dollars for larger ships, to tens of thousands of dollars for very large, specialized ships. Because of these high costs, there is a continuing question whether ships are being used most efficiently and effectively. Of particular concern is whether repeated cruises

to the same area could be avoided if more kinds of data were collected by each ship. Four factors heavily influence the answer to this question. These are ship speed, type of information collected, ship size, and operational areas.

Bathymetric, magnetic, gravity, and seismic data are most efficiently collected with the vessel underway on systematic operating lines. High-quality hydrographic depth data can be collected at speeds up to 25 knots in coastal areas, and bathymetric data of high quality can be collected at 15 knots in deep-sea areas. Geophysical information for general or routine use can also be acquired at 15 knots, but vehicles for near-bottom geophysical surveys in deep water must be towed at 2 knots or less.

On the other hand, geologic samples and much physical, chemical, and biological oceanographic information require collection with the ship stationary in the water, or on station. For certain sampling, such as deep-sea rock dredging and plankton collection, the vessel may drift or be underway at very slow speed; for other types of sampling, more precise station-keeping is required. For deep drilling, the ship must be precisely located for days or weeks by anchor arrays in shallow water or by automated positioning equipment in deep water. Also, many different kinds of geologic and oceanographic sampling and measurement may be made at a station, but few can be made simultaneously. In deep water, for example, only one bottom or near-bottom operation can be carried on at a time to avoid tangled lines. Successive operations may each involve several hours or more.

Finally, a relatively small shore-based launch which returns to port at the end of each day may be adequate to conduct hydrographic surveys along the Atlantic and Gulf Coasts, where supplies and services are readily available. On the other hand, a vessel of the same size engaged in precisely the same type of survey work in the Aleutian Islands area will require a mother ship. Where rough weather is frequently experienced for extended periods, ship size should be adequate to provide reasonable habitability if data quality is to be maintained.

From the above, we conclude:

- It is unrealistic to attempt to fulfill all requirements for underway marine survey data during a single underway operation.

- It is equally unrealistic to attempt to fulfill all on-station requirements during one on-station operation.

- It may be possible, however, to double up data collection if the operating modes required to collect them are reasonably compatible.

The overall management of the civilian marine survey and research ships has improved significantly over the last few years. NOAA has formulated a Centralized Fleet Management concept which provides centralized funding and technical support for the operations and maintenance of all its ships and ship-base facilities. Concurrently, a Ship Allocation Council has been established. This Council reviews proposals for ship operations made by NOAA program managers, as well as those suggested to NOAA by academic and international program managers, and recommends to the Adminstrator relative priorities for use of NOAA ships and facilities. The Navy assigns blocks of ship time to projects which entail compatible kinds of data-collection activities in order to achieve most effective vessel use. Academic institutions use the same technique, by coordinating operating schedules through UNOLS.

Based on our review of ship capabilities and the agencies' management procedures, we believe the Federal marine survey fleet operators (i.e., Navy, NOAA, CG, NSF), the agencies which charter vessels (e.g., GS), and the academic institutions supported by Federal funds are, in general, doing a good job in achieving effective and efficient ship use under currently existing technological and economic constraints. The introduction of automated data-acquisition and processing equipment has increased data collection speed, reduced the number of personnel required, and provided data that are more complete, more accurate, and more rapidly processable.

We recommend, however, that the Interagency Committee on Marine Science and Engineering review in depth, yearly, the Federal programs requiring marine data collection in light of existing platform capabilities and follow up with specific recommendations to the involved agencies and OMB laying out annual ship-use priorities and long-term ship requirement projection.

TECHNICAL SERVICES

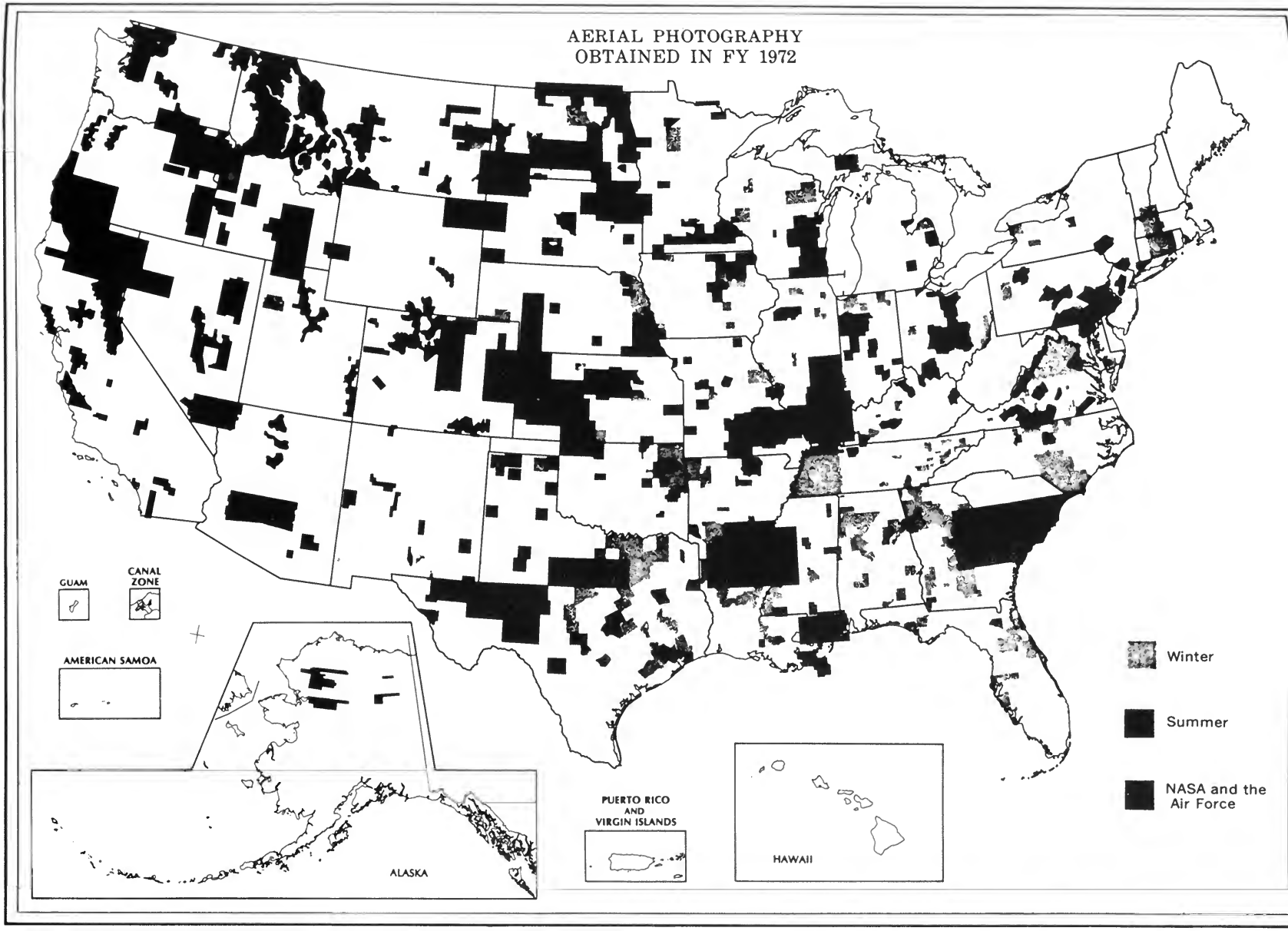
IMAGERY COLLECTION AND PROCESSING

One of our major findings is that, despite substantial expenditures and the existence of ambitious, orderly topographic and geodetic programs, Federal agency needs for maps and control data are not being met. A key factor underlying this deficiency has been the lack of an information data base built on imagery.

A national photo data base requires photographic coverage that must be:

- Current -- less than 3 years of age over areas of medium to high cultural development.
- Of high resolution -- sufficient to resolve detail for a wide spectrum of civilian applications.
- Synoptic in coverage (covering a large area on one photo) -- to afford substantial economies in map production.
- Of sufficient geometric fidelity to support topographic map compilation at scales at least as large as 1:24,000 with appropriate contour intervals.

Expenditures for aerial photography by Federal agencies in 1972 amounted to $6.5 million, with a resultant coverage of slightly over 1,000,000 square miles. Over one-third of the dollar total was spent by NASA for support of earth observation activities. Two-fifths of the coverage was obtained either by NASA (67,000 square miles) or the USAF (337,000 square miles) and was not used to any great extent by the mapping agencies. Thus, 600,000 square miles of aerial photographic coverage was collected at a cost of $4.1 million for various kinds of mapping and interpretation (fig. 20). This coverage was scattered over more than 450 different parcels, ranging in size from 100 to 15,000 square miles and was acquired at altitudes from 5,000 to 40,000 feet. Most of it was obtained on contract with


AERIAL PHOTOGRAPHY
OBTAINED IN FY 1972
GUAM
CANAL ZONE
AMERICAN SAMOA
ALASKA
PUERTO RICO AND VIRGIN ISLANDS
HAWAII
Winter
Summer
NASA and the Air Force

private firms, although the Corps of Engineers, Forest Service, and National Ocean Survey use their own aircraft. A distinct trend is toward higher altitude synoptic photography.

Aerial photographs are obtained to meet requirements of agency programs with varying specifications and constraints. GS uses imagery for mapping and obtains coverage on a nationwide basis. ASCS obtains photographs for measuring crop acreage, and the prime users are the 3,000 ASCS county offices which administer crop allotment, production adjustment, marketing quotas, and other agricultural programs. SCS obtains photographs for a wide variety of conservation projects including soil and water conservation plans, engineering plans and layout, land use, soil investigations, and the like. Of note are the photo atlas sheets for soils surveys and the photo bases for the published soil surveys. FS obtains systematic resource photo coverage over the national forests for updating inventories (e.g., timber, ranges, and soils) and for mapping. DOD domestic coverage is collected mostly in training flights and a little, as a result of specific requests from civilian agencies.

In addition, other agencies obtain limited-area coverage for special-purpose needs of operational programs. It is generally used for large-scale maps and engineering designs, photoidentification of property corners, and detailed resource inventories. Existing photography, which is systematically checked against a central photo index in GS, is rarely found to be suitable for new projects. Attempts to consolidate interagency requirements prior to contracting have been for the most part unsuccessful.

About 22 agencies, which handle photography or do cartographic work in-house, have photo labs. Most of the labs have several functions ranging from the reproduction of photo prints for servicing in-house and external customers to photo reproduction of map manuscripts in support of production. ASCS, EROS, and NASA are the only major labs which do not also provide map production support.

Current procedures for procurement of commercial photography are time consuming and add considerably to the production cycle. From project authorization to contract approval and completion

generally can take 6 to 8 months. In topographic mapping this sometimes stretches out to a year of the 5-year production cycle. ASCS photography comes closest to providing the public with the most comprehensive national coverage, but this is available for only 80 percent of the country and ranges up to 8 years of age. If new technology, as discussed in Photogrammetric Processing, is to be adopted for civilian map and chart production and for resource studies and management, more systematic photo collection will be needed. This would require a centrally coordinated effort against national civilian requirements.

To assure suitable, orderly management of civilian imagery collection, it is necessary to establish a centralized unit to assemble, coordinate, and validate requirements. This unit would have the responsibility of rationalizing the diverse program requirements to assure an efficient and equitable collection scheme, giving full consideration to the basic alignment of collection with production and establishing criteria for priority determinations.

In addition to the coordination function, the requirements unit should be concerned with the preparation and arrangement of requirements, with the development of an accounting system on the status of completion, and with post-collection reviews and assessments.

We recommend that a civilian Mapping and Resource Requirements Committee be established immediately to assemble, review, coordinate, and validate photo requirements of all civilian agencies.

Earth Resources Technology Satellite

The Earth Resources Technology Satellite -- ERTS-1, launched July 23, 1972 -- produces photographic imagery derived from video signals transmitted by two types of imagery sensors -- one, a three-camera television system (Return Beam Vidicon -- RBV), and the other, a multispectral scanner (MSS). Data are transmitted directly when the spacecraft is within range of a reception station. For the U.S., this provides data in real time.

ERTS was not designed to collect data for production of standard cartographic materials. Notwithstanding this fact, many false hopes have been raised by uninformed or careless writers. For example, an article in the publication of the International Monetary Fund and the World Bank Group describes the satellite as an excellent mapping tool and states categorically that "ERTS-A photographs will be used to correct or update regional maps and will provide the first opportunity for detailed mapping of many remote or inaccessible regions. Such maps will be useful, for example, in planning long highways and railroads. Projects to be conducted by scientists in France, the Federal Republic of Germany, and the United Kingdom aim at improving the techniques for mapping from satellite photographs." Such false expectations will inevitably lead to many disappointments. Nevertheless, small-scale mapping with ERTS-1 imagery may be attempted by foreign countries that have incomplete map coverage or lack current photographs.

For the U.S., ERTS-1 will have little or no usefulness for standard map production. The resolution is much too low -- only features with dimensions of 410 to 1,050 feet (and some narrower linear features) can be identified. Neither of the sensor systems provides stereoscopic photographs, and contours cannot be derived.

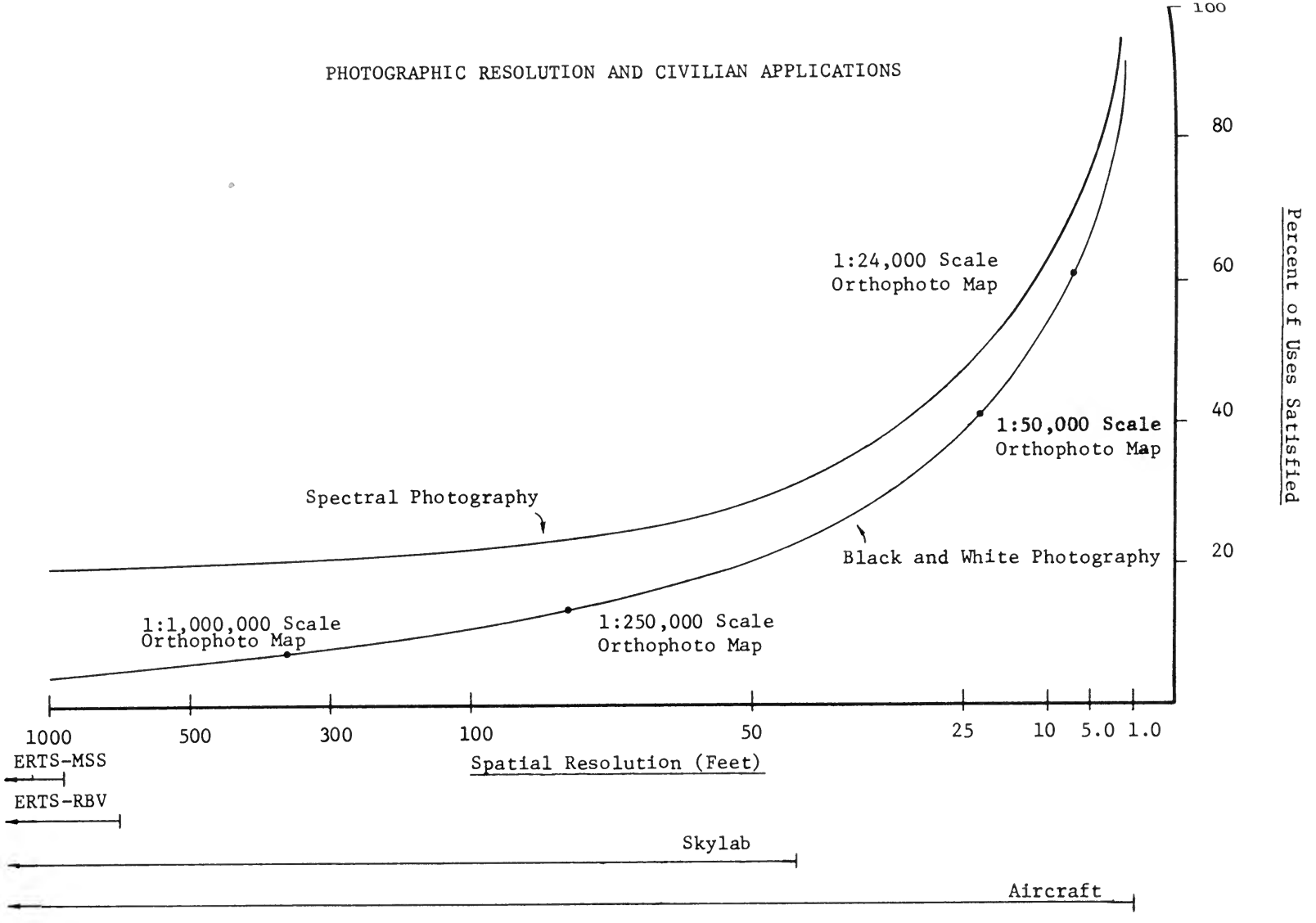
The resolutions are compatible with map-base scales no larger than 1:1,000,000, and little benefit is derived by enlarging the imagery beyond this scale. Geometric properties indicate suitability for scale no larger than 1:250,000, which is achieved at the expense of image quality. GS, with NASA funding, is experimenting with the preparation of a planimetric photoimage base map, and if user demand is sufficient, coverage will be prepared for the entire U.S. The sample products to date at 1:250,000 scale are not very promising. The quality of the input materials points towards a scale no larger than 1:500,000.

Some limited amount of planimetric revision of line maps might be possible from ERTS-1 imagery, but the image quality is inadequate for many of the features required for a revision. In view of the ongoing GS revision of the 1:250,000-scale map series, the only justification for the production of a 1:250,000-scale photomap is the additional photographic detail not shown on the line map. Whether this additional detail is sufficient to warrant the cost of production will require further study. In view of the clear overall superiority of available higher resolution photography, the only other advantages now apparent in the issuance of an ERTS photomap series is that the photographic detail, where legible, may be somewhat more up-to-date.

The appeal of photomaps is in their outstanding versatility for showing full landscape information, for enhancing the presentation of overlay information, for highlighting selected elements of a scene, and for specialized display of complex ground information. In the face of the availability of higher resolution photography, ERTS imagery with its small scale and low resolution will be of limited value. On the other hand, its unique multispectral information is known to disclose some data not visible in black and white imagery regardless of scale or resolution. Identifying these data and their cost benefits is currently the objective of NASA-funded investigations and a NASA-chaired Interagency Coordination Committee for Earth Resource Survey Program. But both fall short because they are not comparing the marginal value of ERTS against existing collection.

In the absence of such comparative analysis, we undertook to assess how imagery resolution affects satisfaction of data requirements for resource surveys and analysis selected from approved ERTS and SKYLAB proposals and from other relevant articles and publications. The result is presented in (fig. 21). Not surprisingly, the curves show that high resolution satisfies more requirements than low, that spectral coverage adds more to low-resolution systems than to high, and that the incremental gain from spectral over high-resolution black and white is very small. Benefits from repetitive coverage are not shown, and the comparison makes no attempt to take the relative importance of applications into account. In other words, how valuable is the small increment provided by spectral over existing high-resolution photography? This question still must be answered.

Figure 21


PHOTOGRAPHIC RESOLUTION AND CIVILIAN APPLICATIONS
100
80
60
40
20
Percent of Uses Satisfied
1:24,000 Scale
Orthophoto Map
1:50,000 Scale
Orthophoto Map
Spectral Photography
Black and White Photography
1:1,000,000 Scale
Orthophoto Map
1:250,000 Scale
Orthophoto Map
1000
500
300
100
50
25
10
5.0
1.0
Spatial Resolution (Feet)
ERTS-MSS
ERTS-RBV
Skylab
Aircraft

PHOTOGRAMMETRIC PROCESSING

We found that 14 Federal agencies spent approximately $18 million and 1,105 man-years in FY 1972 for photogrammetric activities, including aerotriangulation, map compilation, and special-purpose delineation and measurement. The largest single civilian user of photogrammetry is the Geological Survey in the National Topographic Program. NOS, SCS, FS, and TVA use photogrammetry in their systematic mapping and charting programs, and many other agencies use it in making large-scale, single-purpose maps and measurements over limited areas.

The accuracies achieved and complexity of photogrammetric techniques vary considerably. Procedures and equipment used are chosen to be compatible with product requirements. For example, GS uses analytical aerotriangulation and conventional stereoplotters to achieve rigorous accuracy standards as do other agencies involved in systematic programs; FS, CE, BR, and BLM use similar techniques in preparing large-scale maps and making precise measurements for engineering and cadastral computations. Others use less sophisticated aerotriangulation and image rectification when high accuracies are not required (e.g., soils mapping by SCS).

Agencies engaged in national systematic mapping programs do nearly all of their photogrammetric work in-house. On the other hand, much of the special-purpose, small-area work is done by contract, and private industry has a strong interest and capability in this field.

All of the civilian agencies use conventional frame photographs (usually 9 x 9 in.). Their equipment is designed to accept this standard format and several focal lengths (6 in., 8 1/4 in., and some 12 in. and 3 1/2 in.). Aerial triangulation software is designed primarily to handle these materials. The technology for use of aircraft photography has been largely developed over the past 30 years, and state-of-the-art is now very similar among the civilian agencies. Past studies and several years of experience

by DOD clearly show that significant advantages can be realized by use of advanced technology in the preparation of a number of MC&G products and data.

Both theoretical and practical tests have been undertaken by DMA to determine achievable accuracies and production costs for various classes of products, including small- and medium-scale line maps (1:200,000 and smaller), large-scale maps (1:2,400 to 1:50,000), map revisions, and positional data.

Even though it is technically feasible to fulfill many civilian MC&G requirements by use of advanced technology, there would be no point in changing from existing procedures simply because it can be done. There must be reasonable expectation of increased effectiveness and efficiency -- measured in time or money or both.

We have compared the cost of using new technology with the cost of present photogrammetric practices for the major civilian products. We estimate annual savings of more than $4 million, predicated on the availability of adequate data and analytical mensuration and compilation equipment, adequate technical support, and trained personnel -- all of which must be capitalized.

But to project hard savings with a high degree of assurance from knowhow developed against similar but different products is fatuous, if not downright foolhardy. Nevertheless, we are confident that over the years substantial savings will be realized as a result of the reduced need for field surveys for control and the ability to produce interim products and related data quickly and responsively.

Further testing and actual production experience will be necessary to determine cost/benefit ratios. But, if our cost analyses are anywhere near correct, use of current DOD technology can offer significant increases in effectiveness, responsiveness, and overall savings.

Topographic mapping of the 1:63,360-scale series (Alaska) and of the 1:24,000-scale series at 40-foot contour interval are

excellent low-risk starting points for developing a production program. Moreover, the revision program, already started, should be more broadly applied to most kinds of civilian line maps. Immediate application is also seen in the collection of digital terrain and resource data for Federal land-management activities which should be implemented. As techniques are developed and materials and equipment become available, production of the 20-foot contour interval, 1:24,000-scale quads can be added. Further commitment should also be made on the basis of a thorough review of the expected program 5 to 10 years hence, taking into account new equipment that will be better suited for civilian jobs.

Realizing the full potential of advanced technology requires that the civilian community acquire analytical plotter capability. Developing that capability involves not just the installation of instruments but also training of operators, equipment maintenance, new facility and space arrangments and redistribution of production resources as new procedures are phased into operation. Such a capability now exists only in the Defense Mapping Agency which has had several years of operational experience in mapping with the AS-11 and the UNAMACE. We believe that the AS-11 is better suited to civilian applications because of its flexibility in configuration, lower cost, and higher probability of being available. DMA currently has approximately 39 operational AS-11 plotters located in St. Louis and Washington, which are being fully used, most on a two-shift basis. DMA has programmed for replacement of some of the earlier models (eight AS-11A's) beginning in 1975 although funding approval has not been obtained.

The actual number of instruments needed for civilian application and their configurations will depend on the type of products (i.e., line maps, orthophotos, digital data) and the extent of the program to be accomplished. For example, current annual production of 20- and 40-foot contour interval new mapping (approximately 46,000 sq. miles) would require up to 20 analytical plotters working full time. Although we are not prepared to recommend an immediate commitment to produce that much new mapping annually, we do believe it is a reasonable goal. Projected 10-year net

savings based on a program of this magnitude, considering investment costs (current equipment design), could be as much as $8.6 million (fig. 22). Immediate action should be taken by GS to acquire an analytical plotter capability for further tests to establish the cost effectiveness of the system.

The pacing factors in developing a capability are the rate at which analytical plotters become available and the management commitment to use them. We considered several alternative analytical plotter procurement plans. These plans provide a basis whereby management can decide on the proper course of action in developing a plotter capability, and they provide a means to determine the short-term cost and long-term savings. Each plan considered the cost of the various analytical plotter configurations and the time frame in which they could be made available. All include the assumption that some equipment would be provided by DOD and that the civilian agency (GS) would be able to take advantage of DOD R&D programs to aid in the modification and development of equipment.

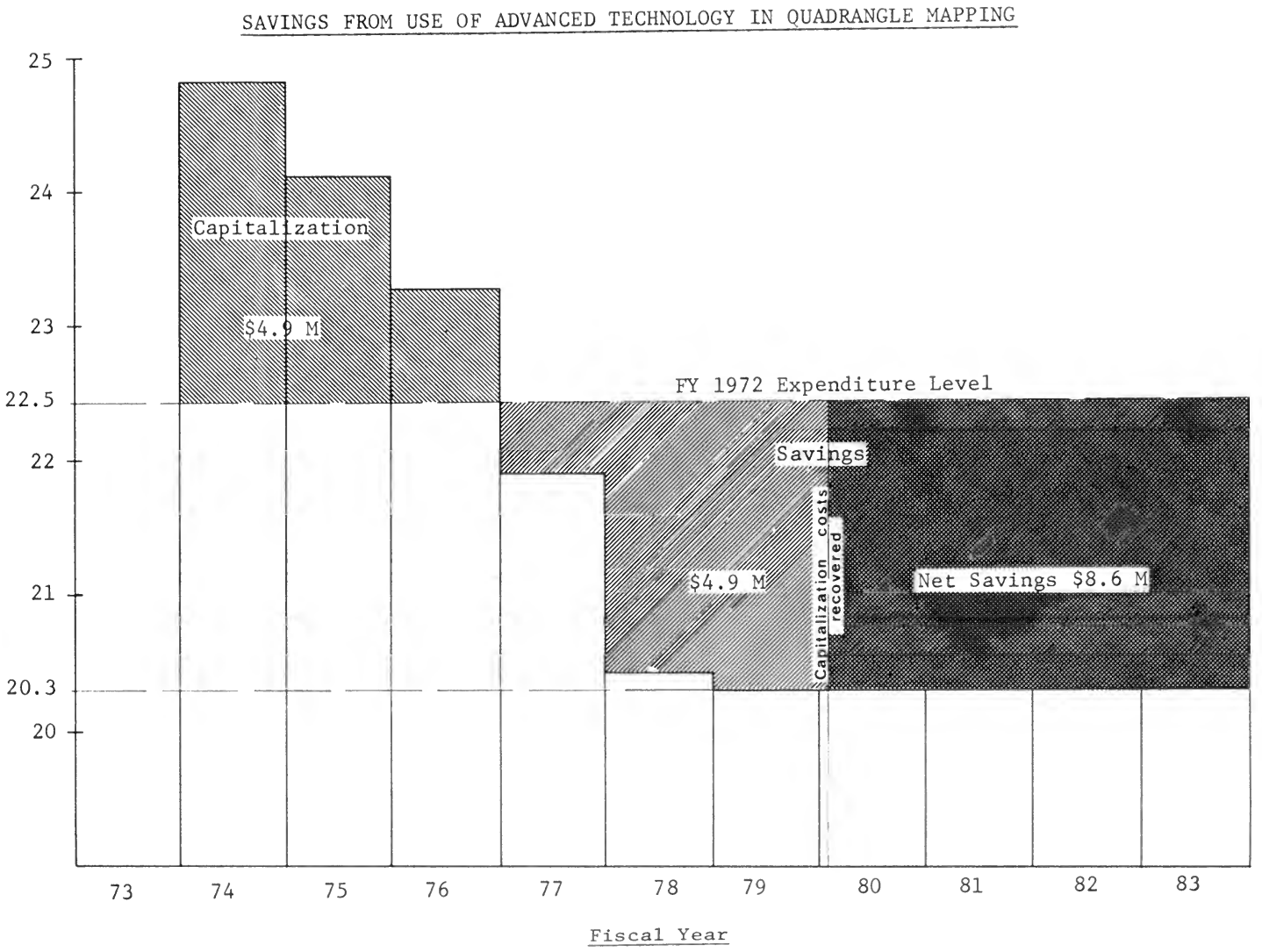
We recommend that:

- *GS take immediate action to obtain an analytical plotter capability at its Special Mapping Center in Reston, Va. Consideration should be given to the needs of other civilian agencies, as well as those of GS, in determining equipment configuration.*

- *DMA provide, on a long-term loan, two AS-11 analytical plotters to GS immediately (DMA has already responded positively to such a request). We believe such a step best serves the overall national interest even though it presses DMA into additional multiple-shift operations to maintain production.*

- *DMA assist in training personnel, development of software capability, and modification and procurement of equipment as necessary.*

Figure 22


SAVINGS FROM USE OF ADVANCED TECHNOLOGY IN QUADRANGLE MAPPING
Program Costs ($ in Millions)
25
24
23
22.5
22
21
20.3
20
Capitalization
$4.9 M
FY 1972 Expenditure Level
Savings
$4.9 M
Capitalization costs recovered
Net Savings $8.6 M
73
74
75
76
77
78
79
80
81
82
83
Fiscal Year

- *Steps be taken to procure additional plotters, either through purchase of equipment specifically designed for the civilian community or modification of those which are to be replaced by DMA. The exact number and type should be a decision of the program manager on the basis of a detailed analysis of the projected activity. Such an analysis should begin immediately.*

CARTOGRAPHY

Eighteen Federal agencies expended $37.5 million and 2,500 man-years on cartography as shown in table 8. This effort includes domestic cartographic compilation and map finishing but not the photographic processing discussed in the previous section. Most of the cartographic work is accomplished in-house at numerous facilities throughout the country, and the complexity of cartographic techniques varies considerably among the agencies. For example, the efforts of GS, NOS, FS, SCS, SESA, and TVA, approximately $24 million, are devoted to products distributed widely and used for numerous purposes, whereas the remaining civilian agencies usually compile products for internal use, which in most cases have less demanding requirements for content and accuracy. Generally, conventional manual methods of compilation and map finishing prevail through the community.

The present skills and techniques used in the community, particularly in the national programs, are sufficiently compatible to allow shifts of work between programs with little lost motion, but we found little evidence that such shifts are considered by the agencies.

We also found that major agencies with cartographic capability are in the process of developing and implementing computer-assisted automated systems, although no complete system has emerged. So far, there has been no concerted effort to make these separately developed systems compatible with each other. The individual efforts are not adequately funded or broad enough to provide for the development or operation of a totally automated capability. Complicating the situation are fast-growing requirements to understand the proper relationships of points and areas to social, ecological, and economic phenomena, in any combination, and to present them in digital or hard-copy form. These requirements are influential in the establishment of numerous computer-assisted systems throughout the Government. Several Federal departments and independent agencies are developing such systems, and each projects a massive expansion to support its social, envoronmental, or resource mission. They have a common requirement for positioning data geographically,

TABLE 8

CARTOGRAPHY

(FY 1972 Expenditures in Thousands of Dollars)

Agency	National Topographic Mapping		Aeronautical Charting		Nautical Charting		Soils Mapping		Geologic Mapping		Planimetric Mapping		Cadastral Mapping		Other Topographic Mapping		Other Thematic Mapping		Total	
	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY	$	MY
DEPARTMENT OF DEFENSE																				
Defense Mapping Agency	-	-	2,457	147	-	-	-	-	-	-	-	-	-	-	531	39	104	5	3,092	191
Navy Operations	-	-	-	-	441	22	-	-	-	-	-	-	-	-	-	-	-	-	441	22
Corps of Engineers, U. S. Army,	-	-	-	-	14	1	-	-	-	-	171	18	32	4	940	67	588	40	1,745	130
Mississippi River Commission, U. S. Army	132	9	-	-	13	1	-	-	-	-	32	-	67	7	90	9	46	4	380	30
TOTAL - DEFENSE	132	9	2,457	147	468	24					203	18	99	11	1,561	115	738	49	5,658	373
DEPARTMENT OF THE INTERIOR																				
Topographic Division, Geological Survey (GS)	8,519	427	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,160	57	9,679	484
Publications Division, GS	-	-	-	-	-	-	-	-	874	44	-	-	-	-	-	-	587	29	1,461	73
Bureau of Land Management	-	-	-	-	-	-	-	-	-	-	315	33	635	44	-	-	1,464	114	2,414	191
National Park Service	-	-	-	-	-	-	-	-	-	-	126	6	327	25	57	15	-	-	510	46
Bureau of Reclamation	-	-	-	-	-	-	-	-	-	-	-	-	127	11	363	30	-	-	490	41
Bureau of Sport Fisheries & Wildlife	-	-	-	-	-	-	-	-	-	-	-	-	109	11	-	-	-	-	109	11
Bureau of Indian Affairs	-	-	-	-	-	-	-	-	-	-	58	7	-	-	-	-	-	-	58	7
Bonneville Power Administration	-	-	-	-	-	-	-	-	-	-	421	41	-	-	-	-	-	-	421	41
TOTAL - INTERIOR	8,519	427							874	44	920	87	1,198	91	420	45	3,211	200	15,142	894
DEPARTMENT OF AGRICULTURE																				
Soil Conservation Service	-	-	-	-	-	-	2,347	162	-	-	216	21	-	-	-	-	118	12	2,681	195
Forest Service	280	30	-	-	-	-	-	-	-	-	214	23	59	7	185	20	456	48	1,194	128
TOTAL - AGRICULTURE	280	30					2,347	162			430	44	59	7	185	20	574	60	3,875	323
DEPARTMENT OF COMMERCE																				
National Ocean Survey, National Oceanic & Atmospheric Administration	-	-	4,933	294	2,258	120	-	-	-	-	-	-	-	-	-	-	252	14	7,443	428
Bureau of Census, SESA	-	-	-	-	-	-	-	-	-	-	419	59	-	-	-	-	112	13	531	72
TOTAL - COMMERCE			4,933	294	2,258	120					419	59					364	27	7,974	500
DEPARTMENT OF TRANSPORTATION																				
Federal Highway Administration	-	-	-	-	-	-	-	-	-	-	3,531	351	96	9	49	5	268	26	3,944	391
INDEPENDENT AGENCIES																				
Atomic Energy Commission	-	-	-	-	-	-		-	34	1	-	-	-	-	-	-	46	4	80	5
Tennessee Valley Authority	267	18	-	-	4	-	-	-	30	2	133	9	171	11	102	7	108	8	815	55
TOTAL - INDEPENDENT AGENCIES	267	18			4				64	3	133	9	171	11	102	7	154	12	895	60
TOTAL	9,198	484	7,390	441	2,730	144	2,347	162	938	47	5,636	568	1,623	129	2,317	192	5,309	374	37,488	2,541

but most of their systems are not being designed on the basis of common cartographic principles. The overall national effort to collect and store interrelated spatial data, therefore, can be facilitated by implementing standard automated procedures based on knowledge and principles inherent in the cartographic process.

We conclude that, through centralized management of cartographic functions and subsequent aggressive implementation of computer-assisted techniques for digitizing and displaying spatial data, the following advantages will accrue:

- Formation of a sufficiently large base to support fast-growing requirements.
- Greater flexibility to manipulate and portray massive amounts of time-sensitive data through integrating imcomplete existing systems.
- Production of digitized information as well as standard hard-copy products during one operation.
- Reduced manpower per unit of output.
- Shortened map and chart production cycle.

We therefore recommend centralization of appropriate cartographic functions and skills within the new agency, consistent with the proposals discussed in the Marine Mapping and Charting and Related Surveys, Land Mapping, and Aeronautical Charting sections. Also, the new agency should provide a common reference system (standards and specifications) for displaying spatial data and coordinate the development of information systems for displaying these data.

PRINTING AND DISTRIBUTION

Printing

Eighteen Federal Agencies spent $9.5 million in FY 1972 for printing domestic maps and charts. Four agencies (three civilian and one military) operate MC&G reproduction plants. The three civilian agencies account for 60 percent of the printing expenditures for the total community (GS 32%, NOS 22%, SCS 6%). Other printing is accomplished through contracts with commercial firms.

The following summarizes the programs of the four major MC&G in-house printing plants.

Agency	Plant Location	Expenditures MY	Expenditures $K
National Ocean Survey	Washington, D.C.	101	2,007
DMA Aerospace Center	St. Louis, Mo.	24	2,566*
Geological Survey	Washington, D.C.	128	3,100
Soil Conservation Service	Hyattsville, Md. Lincoln, Neb. Ft. Worth, Tex. Portland, Ore.	10	404
	Totals	263	8,077

*Military domestic operations only.

Material, equipment, and manpower skills in these plants are similar -- so similar that printing could be shifted from program to program to handle peak workloads as national priorities dictate with very little lost motion. Little cross servicing is now going on, however, mainly due to misguided control exercised by the Congressional Joint Committee on Printing (JCP). This committee has jurisdiction over all government printing activities either

directly or through the Government Printing Office (GPO). JCP has legislative clout to "use any measures it considers necessary to remedy neglect, delay, duplication, or waste in the public printing and binding and the distribution of Government publications" (Government Printing and Binding Regulations - April 1971). This power has been translated into a concentrated effort to reduce, even to zero, any and all Federal in-house printing operations. But because of the limited number of commercial printing firms who can competitively and responsively meet required quality standards for maps and charts, MC&G agencies have managed to hold on to in-house plants. Even so, the dead hand of JCP has caused effectiveness in these plants to drop:

- Obsolescent equipment is not replaced because JCP looks unkindly on new purchases.
- Multicolor jobs are run inefficiently on single-color presses.
- Inferior paper is purchased because GPO fails to exercise proper quality control over vendor contracts.
- Rules governing printing discourage optimum interagency use of the Government's capability. Agencies with no in-house capacity contract with commercial firms at greater cost and with an additional 6 percent surcharge to GPO for handling the contracts. Worse yet, in one instance an agency does in-house printing and is still charged 6 percent by GPO.

Distribution

Eleven agencies spent $4.3 million in FY 1972 to distribute nearly 50 million copies of maps and charts. The two largest distributors are NOS (35.7 million copies) and GS (9.5 million copies). These are also the only agencies with large warehouse-type distribution facilities (NOS has one, and GS, four) and organized sales-agent networks. The other agencies distribute their products through various outlets such as local offices, county agricultural agents, GPO, or Congress. Some agencies limit distribution to in-house or other government uses.

The primary objective of distribution is simply getting the right product to the customer in a responsive and efficient manner. But not enough consumers are aware of the existence of products and how or where to obtain them. They now must often inquire of several different agencies before they find what they need. This problem can be attributed to:

- Absence of a central MC&G clearinghouse with access to all products.
- Prohibitions or limitations on public relations and advertising.
- Limited use of modern merchandising techniques.

Opportunities for Improved Management

In summary, we have concluded that the major problems in printing and distribution of Federal MC&G products are:

- Congressional control over Federal printing has stymied effective management of plants and thus has reduced efficiency.
- Lack of central control over distribution and information services has reduced the use and corresponding benefits of MC&G products because many potential users are unaware of the various sources of the products.

These problems can best be dealt with through a centralized MC&G agency with authority and resources to manage the printing and distribution of major civilian map and chart products. The central agency concept can afford substantial economies by providing:

- Single-agency liaison with GPO and JCP to handle all Federal map and chart printing, whether or not the products were compiled by the central agency.
- More consistency in printing standards and specifications.

- Better use of all in-house plants through creation of services of common concern.

- Single-source information service for all users to acquire map and chart products.

- Consolidated implementation of modern, efficient, merchandising techniques.

We recommend giving a central MC&G agency full responsibility and authority for managing the printing (rather than GPO) and distribution of its Federal map and chart products. The agency should seek to obtain a blanket waiver from JCP to contract map and chart printing directly with private industry. Significant savings could accrue ($0.5 to $1 million annually) by more efficient use of presses and distribution facilities and by eliminating the middleman in contracting.

DATA AND INFORMATION SYSTEMS

We found that 19 Federal agencies spent approximately $9.6 million in FY 1972 for accessing, storing, and disseminating domestic MC&G data and related information. In addition, at least 30 other agencies maintained library, archival, or reference holdings.

The status of individual files and data-handling systems in the community varies considerably:

Map and Chart Libraries.--Maps are currently held by dozens of agencies. The files may be classed as: (1) operational -- most agencies; (2) archival -- National Archives and Library of Congress; or (3) cross-servicing data centers -- an example of which is Geological Survey's Map Information Office. MIO's map holdings are limited primarily to topographic maps. Most planimetric and other special-purpose maps are held only by the producing agencies.

Nautical charts are held by relatively few agencies -- NOS, DMA, TVA, CG, and CE have operational files, while Library of Congress and National Archives have archival holdings. NOS maintains a data center for nautical charts.

FAA has a comprehensive file of all U.S. aeronautical information, including charts. NOS and DMA maintain operational and servicing chart files for their respective areas of responsibility.

Photo Repositories.--Photographs are held by at least 27 agencies. MIO maintains only a reference file for imagery obtained by most agencies, whereas the Geological Survey's EROS Data Center at Sioux Falls, S.D., has been designated as a national repository for EROS satellite imagery and conventional aerial photographs. It recently began to inventory and access holdings from other agencies. The Agricultural Stabilization and Conservation Service maintains major photo repositories at Asheville, N.C., and Salt Lake City, Utah, with coverage of all major U.S. croplands (79% of the total land area, excluding Alaska). The holdings are updated about every 6 years.

MC&G Data Files.--MC&G data are dispersed in many files as follows:

- Geodetic control is held by approximately 30 agencies. NOS presently collects control for other agencies but only distributes first- and second-order geodetic control data. GS through MIO disseminates only GS third- and lower-order control. DMA created a consolidated file of domestic control, which is not now being actively maintained. Other agencies maintain operational files of varying multipurpose value. Little of the geodetic data has been microfilmed by any agency.

- Topographic data exist mostly in the form of maps and charts, with only a small amount digitized, although DMA has collected digitial terrain information over most of the country -- from the 1:250,000-scale topographic maps. EPA has contracted for the digitization of drainage information over the entire country using a variety of maps as the basic source.

- Marine data by type and by agency holdings are summarized as follows:

Type of Data	Purpose for Holding Data: Operational	Data Center/Library
Bathymetric	Navy, DMA, NOAA	DMA, NOAA
Magnetic	Navy, GS, NOAA	NOAA, Navy
Gravity	GS, TVA, AEC, Navy, NOAA	AEC, TVA, DMA, NOAA
Seismic Profiles	NOAA, GS, Navy	NOAA
Hydrographic	CE, NOAA, GS, DMA, Navy, CG, TVA	DMA, NOAA

Most of the data have been collected for different purposes from various geographic areas, and although fragmemtation is not a serious problem, there is no single source to which a user can direct his query. Modern computer/microfilm-assisted systems for data storage and handling are being used to a limited degree, but they vary among agencies.

- o Geographic names are held in operational files by the major Federal mapping and charting agenices. GS has begun to automate its geographic names file, which will ultimately include seven million place names. GS also provides staff support to the Board on Geographic Names for domestic areas.

Related Data Files.--Various MC&G-related data are generally stored in operational files by the producing agency:

- o Hydrologic -- GS maintains a catalog of information on water data acquisition by 12 Federal and 159 non-Federal agenices under the aegis of OMB Circular A-67. A new automated system called National Water Data Exchange (NAWDEX) is being developed to give descriptive information on the location, extent, quantity, quality, availability, and use of water resources.

- o Soils -- SCS holds published soil surveys, and FS holds soils data for management of National Forests. A large body of data in the form of annotated photographs exists at both agencies.

- o Geologic -- GS holds most geologic data that are of national significance.

- o Land use -- Very little land-use data is held anywhere yet, but new legislation may soon drive a major national program to develop these data.

- o Cadastral (boundary) -- Most agencies hold Federal, State, and county boundary data. Land-management agencies hold boundary information for their areas of interest.

Problems with Existing Systems

No all-source library or common filing or reference system now exists in the community. Only users working within a given discipline are aware of the location of pertinent data and information. To some users, the search can end in frustration and an attitude of

"I'd rather do it myself." For example, if the Corps of Engineers needs to collect all available MC&G data for a specific area in support of a preliminary flood-control plan, it may have to request data as follows:

Base maps -- GS, SESA, SCS, FS, FHWA, and BLM.

Geodetic control -- NOS, GS, FS, and FHWA.

Cadastral data -- BLM.

Soil maps -- SCS and FS.

Geologic maps -- GS.

Aerial photographs -- GS, SCS, ASCS, NASA, FS, NOS, and DOD.

A few files, such as TVA's, are nearly complete for specific geographic areas. The GS Map Information Office accesses most land maps and references most aerial imagery of national interest and some geodetic control performed by others; it does not access nautical and aeronautical charts. NOS only provides geodetic control data of first- and second-order accuracy. The EROS Data Center has only begun to collect imagery data from other agencies. These deficiencies can lead to a Federal agency using less than the best available data or procuring additional data.

The data files that do exist are passive. Data of potential multiple use often remain in agency project files and may be lost altogether or made available to others only on special request. For example, FS maps and geodetic control held by FS and BR are not actively made available to all potential users.

Standard reference systems do not exist. Many different coding and coordinate systems are used. Approximately 10 agencies now have visible programs for collecting and handling digital information. Some agencies have collected data for specific elements over most of the country (DMA -- terrain, EPA -- drainage), but each project has

been done to meet a specific user requirement. There is no comprehensive, systematic program for the orderly collection of digital data for an entire map series. Although some map elements are being digitized as input for computer-assisted cartography, no central index is available for these data, and the data are often discovered accidently. There is no standard format for referencing, storing, and retrieving data. A user must, therefore, become familiar with many different reference systems to query the different files and then may end up with data based on several systems, which he must correlate.

Very few modern computer/microfilm-assisted data-handling systems are in use. Some agencies, such as ASCS, have very efficient manual systems for handling their own materials, but those systems are not readily compatible with others and can thus restrict or complicate the interchange of data. The automated systems that are in use are generally limited in scope and tied to computers not available to all users.

The exact cost of the inefficiency caused by these problems is elusive, but we consider the inefficiency significant and in need of early correction. The cost is related to wasted time and manpower in searching for existing data and to inefficiency of out-of-date data-handling systems. Perhaps the greatest cost is an indirect one -- the excessive cost to the user of doing his job with less than the best information. There is little evidence of production duplication that can be traced directly to data problems; however, examples of duplication cited elsewhere under both mapping and surveying have certainly been aggravated by this fragmentation of data holdings. No doubt duplicative data acquisition results from ineffective data-handling procedures throughout the MC&G community. A data-collection program cannot be effectively managed if the data gaps cannot be identified.

Current Effort to Solve the Problems

Agencies and units in the MC&G community will always have a legitimate need for operational files of data related to their specific missions. These files should remain close to the operating units. Something more is needed, however, to service all users on a crosscutting basis.

A National Cartographic Information Center (NCIC), as conceived by GS, will contain most of the elements of an all-source system for the community, except for marine data. It has been designed to build on the nucleus and mission of MIO to encompass cartographic information from Federal, State, and local governments and the private sector. For example, ASCS photographs, NOS geodetic control, and FS maps are all to be included. Commercial photography holdings, county maps, and the like will also be inventoried and considered for inclusion. Hard copy of all data is not necessarily to be pulled in. Some items will only be indexed, some microfilmed (with mono-color blowback service), and others will be stored in full-size hard copy. Even though total centralized storage is not planned, all significant what-is-it and where-is-it questions are to be answered.

The Resource and Land Information (RALI) program, as conceived by Interior and administered by GS, is designed to access, store, and disseminate an extensive array of spatial information, much of which is not normally handled within the general-purpose mapping process. Data related to Federal land ownership, water, forest range, geology, vegetation, soil conditions, and land-management plans are to be included.

A land-use classification and coding scheme was recently developed as a result of the "Conference on Land Use Information and Classification" (June 28-30, 1971). This interagency effort grew out of the joint concerns of officials from Interior's EROS program and NASA's Earth Resources Survey, who were jointly supporting a Geographic Applications Program in the Geological Survey. The scheme represents an amalgamation of Federal requirements and existing systems. It considers various levels of intensity from the gross synoptic information achievable through the use of ERTS to the detailed classifications achievable through the use of high-resolution aircraft photos or ground investigations.

In conclusion, we believe that a comprehensive map and chart library, photographic file, and appropriate MC&G data files can be established with the resources which are now devoted to accessing, storing, and disseminating domestic MC&G data.

We recommend that the new agency create a map and chart library, photo repository, and MC&G data files as follows:

- *Map and Chart Library -- Access hard copy of reproducible products, such as:*
  - *All topographic map series.*
  - *State maps.*
  - *County maps.*
  - *SESA metropolitan map series.*
  - *Federal land administration maps.*
  - *All nautical charts and related publications.*
  - *Marine geophysical publications.*
  - *Aeronautical charts.*

  Reference (know and tell about) all other products which receive cartographic treatment, accept orders, and sell finished and reproducible copy of all accessed data.

- *Photo Repository -- Access reproducible copies of domestic photographs as follows:*
  - *Federally procured aircraft coverage of 100 square miles or greater.*
  - *Other significant Federal and commercial coverage as available.*

- *MC&G Data Centers -- Access, store, and disseminate data as follows:*

- *Geodetic -- data produced by GS, TVA, and others as recommended in the Land Survey section.*

- *Topographic -- data obtained during map compilation as discussed in the section on Land Mapping, those data digitized from finished products, and geographic names.*

- *Marine -- unclassified data obtained during and subsequent to the production of marine products and services in areas of interest to civilian programs; and index appropriate classified data.*

To establish a comparable comprehensive file for the Related Data category is a significantly more complicated problem which requires further analysis and investigation. As we were unable to deal with this problem in sufficient depth, no accurate cost estimate can be given, nor for that matter can we recommend a reasonable plan. But because the problem is big and because solution of it is urgent, we believe it should be made the subject of comprehensive study.

Consequently, we recommend that OMB initiate a study to determine how best to deal with this data category.

RESEARCH AND DEVELOPMENT

Although $11.1 million and 440 man-years were identified as resources applied in FY 1972 to MC&G research and development (table 9), only $4.5 million and 175 man-years supported activities directly aimed at improving operational MC&G data collection and processing. These activities, divided among eight different agencies, are generally limited in scope and are in-house oriented. The remaining $6.6 million and 265 man-years were spent by SAO, NASA, and ERL on developing techniques and collecting data for scientific investigations related to earth and ocean physics, geology, and geophysics.

No single agency effort is adequately funded or broad enough in scope to develop and maintain a technological base or assure development of complete systems. Parts of automated cartographic systems have been developed in various agencies, but no total system has emerged. Much of the cartographic R&D effort has been in the areas of digitizing, storage, manipulation, and presentation of spatially oriented data. Several similar, but not necessarily compatible, systems are being developed or implemented for handling information. So far, there is no evidence that these separately developed systems will produce compatible data for use in an overall management scheme.

Photogrammetric R&D in the civilian agencies has concentrated on the development of techniques and instrumentation for applying aircraft photography to standard mapping, orthophotomapping, and terrain digitizing and modelling. It is in the photogrammetric area where DOD agencies have made noteworthy advancements, particularly analytical plotters, automatic correlation, mensuration equipment, and aerotriangulation techniques and reduction programs, which are not being fully exploited by the civilian agencies.

As discussed in the marine mapping and charting section, parallel system development has also occurred in marine data collection and processing, even though different agencies use the same kinds of data for similar applications. Independent development can easily result in a reinvention as well as the design of a system whose output is not compatible with automated chart-compilation systems.

TABLE 9

RESEARCH AND DEVELOPMENT

(FY 1972 -- $ in Thousands)

	Land Surveys		Land Mapping & Charting		Marine Mapping & Charting		Total	
	$	MY	$	MY	$	MY	$	MY
Corps of Engineers	56	4	57	8	-	-	113	12
Topographic Division, GS	169	5	1,643	82	-	-	1,812	87
Forest Service	251	5	-	-	-	-	251	5
National Ocean Survey, NOAA	526	21	154	10	753	30	1,433	61
Environmental Research Laboratories, NOAA	241	7	-	-	3,377	166	3,618	173
Bureau of Census, SESA	-	-	25	2	-	-	25	2
Federal Highway Administration	-	-	24	1	-	-	24	1
Atomic Energy Commission	280	-	-	-	-	-	280	-
National Aeronautics & Space Administration	851	11	-	-	-	-	851	11
Smithsonian Astrophysical Observatory	2,389	88	-	-	-	-	2,389	88
Total	5,043	141	1,903	103	4,130	196	11,076	440

Military and civilian operational mapping and charting programs are funded at close to the same level. But the civilian R&D program in MC&G is small and dispersed, whereas the military R&D program is more adequately funded (four times larger), balanced between in-house and contractual effort, and centrally managed. Consequently, DOD has been able to develop and maintain a technology base beyond that of the civilian community.

Some coordination has taken place among the civilian agencies and between the civilian and DOD agencies on an individual and collective basis. But, significantly, only a small percentage of the people directly involved in civilian R&D projects have appropriate security clearances to learn about classified DOD developments. Technical exchange conferences have been held regularly over the past few years, but they have not had much impact on actual operations or procedures. (Since its creation, DMA has taken the initiative to establish closer coordination with GS and NOS. This includes the specific provision for joint R&D programs and equipment procurement.)

In summary, the fragmented R&D programs of the civilian community produce in-house-oriented results and lead to noncompatibility of products and data as well as duplication in system development. Moreover, fragmentation has produced a condition wherein, with few exceptions, available money is spent primarily for salaries, overhead, and travel -- with little left over for hardware development and prototype procurement. No single agency has the capability to develop the expensive and complicated automated systems necessary to meet growing domestic needs effectively and efficiently. Consolidation of related civilian development efforts will allow more effective use of limited resources, assure compatibility of data between system components, and provide a direct and single interface with DMA.

To make effective use of existing R&D resources and take advantage of the technology base developed by DOD, we recommend: consolidation of R&D activities of the civilian MC&G community within the new agency; establishment of a formal agreement with DMA whereby joint DOD/civilian R&D projects can be carried out, engineering and service testing can be accomplished jointly, and joint procurement of equipment will be accommodated when feasible.

MAP AND CHART PRICING

The formulas used in determining the price at which MC&G products are sold to the public vary agency to agency in accordance with rationale developed from a number of sources and interpretations:

- The Geological Survey establishes prices for topographic maps under Legislative Authority, 43USC42, wiich states: "the Director of the Geological Survey is authorized to dispose of the topographic and geologic maps . . . of the United States, made and published by the Geological Survey, at such prices and under such regulations as may from time to time be fixed by him and approved by the Secretary of the Interior." GS has chosen to recoup the costs of plate-making, printing, bindery, paper, distribution, postage, obsolescence, and spoilage as well as various overhead costs.

- National Ocean Survey policy for pricing navigational charts (nautical and aeronautical) is based on 44USC1307. The original Statute on Pricing was enacted in 1895 and interpretations of that statute, as late as 1961, limited the charges per sheet to cost of paper and press run. In the early 1960's, a dispute arose over the price of air navigation charts between the Government and a private company -- the private company charging unfair competition. A special study committee conducted a review and set forth conclusions in its report. This report, Senate testimony (defining terms contained in a proposed bill, S1336), and legal interpretations of significant words and phrases set forth in the ensuing Public Law 88-441 provide the basis for the present NOS pricing policy. To summarize the statutes and their interpretation, prices of charts for public sale cover full cost to the Government for the printing and distribution phase commencing with costs incurred for actual reproduction of the charts after "original cartography." This phase has been defined to include costs of photography (transferring original cartography to film as the first step in reproduction), opaquing, platemaking,

presswork, bindery operations, postage; and other costs as deemed appropriate by the Secretary of Commerce, which include overhead, administrative expenses associated with the above, and allowance for discounts. These chart prices are to be established at least once each calendar year.

- The Forest Service map pricing authority is contained in the Agricultural Adjustment Act, section 387 (7USC1387), which gives the Secretary of Agriculture authority to furnish maps to the public at a price (not less than estimated cost of reproduction) as the Secretary may determine. Educational and related publications, such as recreational folders, have been interpreted as not falling within the above authority and are made available to the public free.

- The Soil Conservation Service does not sell its cartographic product. Its soil survey publications, including maps and illustrations, are made available to constituents free of charge; however, those publications, if obtained through the Government Printing Office, are sold at a price determined by GPO.

The map and chart producing agencies also have diverse price schedules for products "sold" to Federal users. Some prices are based on policy specified in legislative language requiring recovery of "at least press cost and cost of paper," and other prices are set by agency policy, ranging from 30 percent discounts, to reciprocal exchange agreements, to no charge at all.

Of the above four agencies, GS and NOS have collected some historic data on product price vs. demand. The GS data indicate a sharp drop-off in demand after the 1966 price increase from 30 to 50 cents, although after a 3-year period the volume of sales rose sharply regaining the lost ground, and by 1972 the rate of sales increase approximates a straight line over the decade 1962 to 1972. Analysis of NOS distribution volume vs. price data on subscriptions to specific charts showed a sharp increase in demand from 1964 to 1971, while prices were increased in each of these years. The data following the 1972 price increase, however, showed a subsequent reduction in distribution for

the first time. These data, on aeronautical charts which are revised on a 28-day cycle, imply that users may be reverting to a commercially-produced product available at similar prices.

On the other hand, demand data from a random sample of map and chart users showed some 35 percent responding that an across-the-board price increase of as much as 50 percent would be acceptable. Although we did not obtain definitive quantitative data on relationship of price to sales, we believe:

- Sales to large operators who must have maps and charts to conduct their business would remain constant even if prices were increased significantly.

- Prices of some maps and charts are presently near maximum insofar as increasing government revenue is concerned, but prices of other products can be increased to yield additional revenue.

To get a handle on map and chart pricing practices, we requested producing agencies to submit 1972 data by product showing printing and distribution costs with appropriate overhead folded in, volume and revenue by user category (commercial, private, State and local governments), and volume of free distribution to users. With these data, coupled to the knowledge of agency product distribution procedures, i.e., discounts to agents (for nautical and aeronautical charts), discounts to commercial dealers (for topographic maps), and direct public sales, we worked out standardized pricing criteria applicable to products distributed in quantity to the public. General principles adhered to were:

- Prices for maps, charts, and related publications distributed to non-Federal users should <u>at least</u> return the cost of getting the product to the user.

- Prices should be standardized at a fair market value.

- Prices to Federal users should be standardized at a minimum price (average unit printing and distribution cost) <u>only</u> to keep down excessive requests, since no revenue potential exists.

- Producing agencies should review their policy of free distribution to non-Federal users and reduce this volume to the absolute minimum.

- Standard discounts to dealers and agents should be established.

Proposed standard prices to non-Federal users computed for 17 major products are shown in table 10. These prices can be implemented within the various existing legal authorities. The proposed prices are calculated simply by adding to the average unit cost of printing and distribution a surcharge of 100 percent to cover such costs as transferring cartographic image to film, opaquing and platemaking, as well as agency and department overhead, condemnation, free issues, allowance for agent discounts and then rounding upward to the next 25 cents. To further standardize, a $1.00 minimum for standard maps and charts and a $0.50 minimum for special line products (i.e., aeronautical instrument charts) are proposed as long as these minimums are not less than the computed price. Column 9 shows the price recommended for each product. (Of note, this standardization formula would result in price decreases for some products.)

The estimated revenue gained (column 10) -- $4.7 million per year -- is based on four major assumptions:

- Increased prices will not adversely affect the volume of sales over a period of time.

- The percentage discounts now given agents and dealers will not change appreciably.

- Products which do not now have a distribution mechanism will be distributed the same way as other maps and charts.

- Products now given away free will be sold at the recommended price without loss of volume.

We recommend that map and chart prices to non-Federal users be standardized on the basis of the above rationale and that prices to Federal users be standardized at a minimum amount only to keep down excessive requests.

TABLE 10

Pricing and Distribution Data for MC&G Products in FY 72 and Recommended Standard Pricing

Major Products	Tot. Costs Print. & Dist. $ in Thous. (1)	Tot. Vol. Dist. In Thousands (2)	Avg. Unit Cost Print. & Dist. (3)	Vol. of Dist. to Non-Fed. In Thousands (4)	P&D Cost for Non-Fed. Dist. $ in Thous. (5)	Total Rev. fm. Non-Fed. $ in Thous. (6)	FY 72 Product Price (7)	Computed Product Price (8)	Recomd. Product Price (9)	Est. Revenue Gained $ in Thous. (10)
GS - Topographic maps										
1:24,000 (new & revised)	$3,604	6,370	$0.566	4,360	$2,468	$1,472	$0.50	$1.13	$1.25	$2,208
1:62,500	163	768	0.212	628	133	261	0.50	0.42	1.00	261
1:250,000 (U.S.)	120	240	0.500	191	96	116	0.75	1.00	1.00	39
NOS - Nautical Charts										
Conventional	940	1,561	0.602	743	447	740	1.50	1.20	1.25	-123
Small Craft	226	290	0.779	254	198	341	2.00	1.56	1.75	-53
NOS - Aeronautical Charts										
Planning	12	20	0.600	8	5	9	2.00	1.20	1.25	-3
Sectional & WAC	695	2,179	0.319	1,503	479	686	1.00	0.64	1.00	
Local & Terminal Area	36	161	0.224	69	15	21	0.80	0.45	0.50	-8
Radio Facility	308	3,680	0.084	2,243	188	578	0.50	0.17	0.50	
Aircraft Position	77	243	0.317	219	69	79	0.80	0.64	0.75	-5
IAPC	419	25,460	0.016	22,173	355	496	0.10	0.03	0.10 /1	
FS										
Forest Series	61	311	0.196	1	-	-	Free	0.39	1.00	1
Recreation Folders	363	3,421	0.106	3,421	363	-	Free	0.21	1.00	2,052 /2
SCS										
Soil Survey Publications	470	122	3.850	20	77	-	Free	7.70	7.75	93 /2
CENSUS										
Census Publication Maps	169	279	0.606	251 /3	152	-	Free	1.21	1.25	188 /2
Totals	$7,663				$5,045	$4,799				$4,650 /4

$9,449,000 - Estimated total revenue from non-Federal sales

1/ Products priced by sheet but sold to public in book form (IAPC's) are excluded from 25¢ round-up.
2/ Assumed 40 percent discount for agent cost since there is no sales system now in operation.
3/ Estimated.
4/ Assumed volume of sales remains constant.

Explanation of Columns

Column 1 Agency printing and distribution (P&D) costs.

Column 2 Total volume of distribution (Federal and non-Federal sales and all free).

Column 3 Column 1 divided by column 2.

Column 4 Column 2 minus volume of Federal sales and Federal free (and cooperators for 1:24,000-scale topographic maps).

Column 5 Column 3 times column 4.

Column 6 Non-Federal sales.

Column 7 Current price.

Column 8 Column 3 plus 100 percent surcharge. (The 100 percent increase to cover agency and department overhead, and other expenses incurred.)

Column 9 Column 8 plus round-up to next 25¢, except: $1.00 minimum for Aeronautical Instrument Charts.

Column 10 Estimated total revenue minus column 6 (est. total revenue equals column 6 times column 9 divided by column 7). This assumes that discounts remain the same percent.

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ORGANIZING THE MC&G COMMUNITY

Two major characteristics of the civilian MC&G community today are its diffused management (even though there are numerous common goals) and the interdependence of major MC&G programs and products. That management is diffused is vividly apparent with 39 agencies engaged in the domestic MC&G Federal effort, although only two agencies support the basic, highly visible, multipurpose national programs with less than one-third of the domestic MC&G Federal expenditures. Interdependence is demonstrated and highlighted as follows:

- Geodetic control networks (vertical and horizontal) are fundamental to determining spatial relationships of point and area locations and to construction of nautical and aeronautical charts, topographic maps, and special maps and charts.

- Topographic map information is portrayed on the onshore portion of nautical charts, and marine survey information is added to topographic maps of coastal areas.

- Topographic maps are used in the production of visual aeronautical charts and several series of base maps and as bases for depicting geology, soils, and various other themes.

- Marine survey data (hydrographic, bathymetric, geologic, and some oceanographic) are all entwined throughout various processes of data acquisition, data processing and data presentation.

- Photo collection and processing are essential phases in literally all land mapping and charting activities.

- Photogrammetry, cartography, printing and distribution, and research and development are common technical services to all large mapping and charting programs.

- Land survey activities have like skills, equipment, facilities, and seasonal operational areas whether for mapping, cadastral, or geodetic programs.

- Tidal information is the basis for the nautical chart datum, coastal and seaward boundary determinations, and the Geodetic Vertical Control Network.

We believe Federal civil MC&G resources can be made more productive if a management structure is established to: (1) take full advantage of MC&G commonalities; (2) provide effective communication between consumers and producers; (3) provide fully integrated programs focused toward national goals; and (4) provide well-defined authority to manage and coordinate MC&G activities commensurate with responsibilities.

ORGANIZATIONAL ALTERNATIVES

There are a number of organizational or management alternatives to the status quo which could be implemented. Six alternatives plus the status quo are discussed below with advantages and disadvantages for each.

A New Civilian MC&G Agency (Alternative 1)

With a MC&G budget in excess of $135 million appropriated to the agency and administered by at least a Level V administrator, it would control the national civilian programs of land mapping, geodesy, basic cadastral surveys, nautical and aeronautical charting, marine geophysics and geology activities, and remote survey of earth resources. The agency would provide central cartographic support to soils surveys, Federal land management, geologic investigations, census, environmental protection, and coastal zone management. It would furnish a centrally managed map and chart production capability for the Government; a geographic information center to collect and disseminate geodetic and survey control data, information on maps and charts, and photographic imagery and other remote sensing data from aircraft and space; and a national distribution facility for maps, charts, and related products. It would require eyes and ears in other agencies to help identify requirements, coordinate response, and report potential unmet requirements.

Advantages

- Pinpoints responsibility and accountability. Provides an administration with sufficient stature to do the job.
- Permits major economies through rationalization of community functions and through the elimination of duplicative and redundant capabilities.

Disadvantages

- Gives responsibility to the administrator for managing a large and very complex array of activities which support many diverse and changing national programs of other agencies.

Advantages

- Provides an organization which can deal directly with the Executive Office of the President and Congress, with the Defense Mapping Agency for coordination and support.
- Establishes a management structure that can deal with the kaleidescope of changing requirements played against evolving technology.
- Permits use of expensive sophisticated systems that can be operated efficiently only by a large organization with a big job to do.
- Provides, for the first time, a managerial overview of the comparative value of domestic MC&G functions.
- Provides a central point where using agencies can submit their requirements for MC&G products.
- Offers flexibility in meeting requirements in a more timely way.

Disadvantages

- Centralizing management does not assure that all important Federal requirements will always be met in full and on time.
- Agencies will lose MC&G in-house capabilities which are closely related to their missions. They will strongly resist the transfer on the ground that their program needs cannot be met by a central MC&G agency, no matter how well intentioned.
- Presents initial problems in transferring functions from old, established Federal agencies as well as in establishing the new Federal MC&G identity.
- Depending upon the placement of the new agency, the re-organization could fragment some closely related programs (i.e., ocean charting, mapping, and scientific studies and investigations).

Advantages

- Permits compacting many small, fragmented, R&D operations into an integrated effort geared to solve MC&G problems of national scope.

- Could be implemented by a reorganization plan.

A National MC&G Agency (Alternative 2)

Consolidating the Defense Mapping Agency and the major civil mapping and charting organizations in a single agency would combine the military programs of land mapping, aeronautical charting, nautical charting, marine geophysics, geodetic systems, special products, imagery collection, data management, and printing and distribution with the counterpart civilian programs along with cadastral surveys and cartographic support for soils, geology, land-use, and other earth-resource surveys.

Advantages

- Gets it all together -- similar functions and capabilities managed by one agency.

- Agency resources would be sufficiently large and visible to warrant unique budget review by OMB and the Congress.

- Permits savings and efficiency by combining facilities, instrumentation, and like skills.

Disadvantages

- Presents difficult placement and leadership problems -- any placement (within a civilian or military department or as an independent agency) would have serious organizational drawbacks. Likewise, the choice between military and civilian leadership would also prove vexing.

- Could generate substantial resistance both within DOD and the civilian community.

Advantages	Disadvantages
o Considerable flexibility lent by its broad base would enable quick response to urgent items of high priority.	o Military and civilian consumers and their respective requirements are generally separate by definition of mission.
o Permits overall cross-program analysis for requirement priorities.	o Different areas of interest -- civilian interest is primarily domestic whereas the military is worldwide.
o Facilitates translation of DOD advanced technology into civilian application.	o Defense and civilian budget constraints are different -- changing international tensions could inequitably affect domestic programs.
	o Differing managerial styles would conflict, particularly at operational levels.
	o Requires legislation to implement.

Although this alternative offers considerable promise for an efficient MC&G organization, the current budget environment in which military programs function and the relationships of military MC&G to command and control in the Pentagon argue against this alternative at this time.

A Federal Coordinator in the Executive Office of the President, Office of Management and Budget (Alternative 3)

Under this arrangement, functions and responsibilities of MC&G agencies would remain essentially as they are. The Coordinator would take on the job of program overview by providing guidance on trends and priorities, sponsoring wider communication of plans and programs, identifying voids and overlaps, and conducting studies of MC&G activities as needed.

Advantages

- Provides better communication of issues between the MC&G community and the Executive Office of the President.
- Provides a focal point for cross-program analysis.
- Encourages community responsiveness and thus reduces bureaucratic wrangling.

Disadvantages

- Stimulus for management improvement would be coming primarily from outside the community.
- The Coordinator would soon be regarded in OMB as a program advocate. This is alien to OMB's need to deal with Federal management and budget problems impartially and effectively.
- Agency competition for program support and funds would become sharper, and the programs with the most articulate spokesman would succeed over programs with less effective PR.
- Agencies would resent the constraints placed on their program management by the Coordinator.
- Agency budgets would still be reviewed by different committees of the Congress, reducing the total effect of successful coordination.
- Full-time coordination of MC&G activities would overtax the OMB staff and tend to dilute its overall effectiveness.

A Strengthened Circular A-16 (Alternative 4)

The present Circular A-16 (Coordination of Surveying and Mapping Activities) assigns coordinative lead roles to Interior (GS) for topographic mapping, to Commerce (NOAA/NOS) for geodetic control, and to State for representation of international boundaries on maps and charts. The document is strongly worded but inexplicit as to extent and authority. The document and its mechanics would be improved by broadening the charter to include specifically (1) all domestic mapping activities, not just the National Topographic Program and its interfaces, (2) related surveys, not just the National Geodetic Program, and (3) aeronautical and nautical charting and special-purpose mapping. A staff point of contact would be identified in OMB where major issues could be resolved, helping to keep the coordination process viable. Also more explicit authority would be given to lead agencies with a clearly articulated procedure to be followed. A regularized review of requirements for all products would be included in the provisions of the Circular.

Advantages

- Interior (GS) and Commerce (NOS) would know exactly how much coordination responsibility they have and would have a structure through which to operate.
- Other Federal agencies would understand more clearly what their responsibilities are with regard to Federal coordination and would also have an operating structure.
- Strengthening A-16 with more viable communication between OMB and MC&G would more clearly define Federal MC&G initiatives.

Disadvantages

- Strengthening A-16 is not enough -- cohesive management of the community is required.
- Managing the community by means of a nonfunded coordination mechanism is ineffective.
- No coordinating mechanism (even one supported through the OMB) can long act as a substitute for central control of program and funds.

A Federal Mapping Executive Committee (Alternative 5)

Membership on the committee would consist of Departmental level representatives from Commerce, Interior, Agriculture, Defense, Transportation, Housing and Urban Development, and Executive Office of the President, with provision for at-large membership for further user representation. Standing staff committees would be appointed for Land Mapping, Geodesy and Surveys, Cadastral Surveys, Aeronautical Charting, Nautical Charting, Marine Geophysical Activities, Special-Purpose Mapping, Imagery Collection, and Information Systems. Other special-subject committees would be appointed for the duration of the tasks allotted them by the standing committees. Policies, programs, schedules, and budgets would be reviewed, modified, and approved at periodic meetings, and problem areas would be identified for staff action between meetings. Committee recommendations on major issues would be staffed through OMB and congressional committees. Chairmanship of the Committee would be on a rotating basis.

Advantages

- Level of policy and program review would be sufficiently high to assure implementation of agreed measures.
- Directly involves OMB in a focalized review of overall Federal MC&G activities.
- Facilitates cross-program analysis.
- Consumer representation in the committee structure would improve requirements dialogue.
- Requires no legislation or reorganization plan.

Disadvantages

- Agencies would still tend toward polarity an insularity, and the resulting competition would, as it does now, reduce effectiveness.
- Management of the community and its programs would not be a full-time operation for the committee and its members, which would reduce individual commitment and the quality and effect of the decision-making process.
- The track record of the Executive Committee type of operation is not brilliant.

Disadvantages

- Logrolling can easily replace true coordination -- "If you'll support my large-scale mapping program, I'll support your getting that new ship you want."

Functional Interagency Committees (Alternative 6)

These committees, with membership from the MC&G producing and using agencies, would be established for coordination of such program areas as geodesy, land mapping, nautical charting, marine mapping, aeronautical charting, imagery collection, data information systems, printing and distribution, and research and development. Other committees would be formed for ad hoc tasks. Periodic meetings would be held to discuss plans, programs, and budgets. Reports would be prepared and sent to OMB setting forth areas of agreement and identifying major issues or problem areas.

Advantages

- Coordination or at least communication would be conducted in discreet program areas across agency boundaries.
- Many problem areas would be identified and interagency solutions reached.
- Users of specific products would have a wider forum in which to identify their requirements.

Disadvantages

- Would have insufficient cohesiveness and authority to solve diffuse MC&G management problems or to attack dispersion.
- To arbitrate problem areas, OMB would need a staff to deal with the committees' deliberations.
- Big agencies could belittle important problems of small agencies by sheer weight of program and thus stymie cross-program analysis.

Disadvantages

- The committees' effectiveness would diminish after early enthusiasms have abated, due to lessened commitment and interference with routine duties.

Status Quo

Any discussion of the status quo is somewhat unrealistic, because the community is showing signs of evolution albeit too slow in some cases.

Advantages

- Status quo doesn't rock the boat.
- Does not separate some MC&G activities from the programs they support.

Disadvantages

- Discomfort about community growth and effectiveness will continue.
- No significant improvement will be made in responsiveness to unmet needs and in community-wide coordinated effort toward common goals.
- Fragmentation of effort in R&D and advances in technology will continue in isolated single-program support, without the strength that would accrue from a combined effort.
- Efforts to apply single-purpose work in multipurpose directions will tend to be thwarted.
- Because of its diffusion, the community will not be fully responsive overall to changing and growing requirements.

PROPOSED NEW ORGANIZATION OF MC&G

The sensitivity of the MC&G community to the issues raised by our investigation will likely upset the status quo in any case. If no reorganization effort is made, response of the community to new initiatives and procedures will prompt definitive improvement in the way tasks are defined and approached. It is clear, however, that these enthusiasms will wane and evolution will again lag behind growth. The ideal solution is to press for reorganization, integration of major programs, and coordination of related activities. Only in this way can the community hope to catch the brass ring of optimum effectiveness.

After a careful and thorough evaluation of all advantages and disadvantages of each alternative, we firmly believe that a new civilian MC&G organization (Alternative 1) offers by far the best solution.

We recommend, therefore, creation of a central civilian MC&G agency -- which we would call the Federal Survey Administration (FSA).

The Federal Survey Administration will bring together into one agency the significant MC&G programs (and supporting data-collection activities) that are systematic and national in scope and multipurpose in concept. It will be given the capabilities and mandate required to plan, establish priorities, weigh alternatives and priorities, and operate MC&G programs so that they can provide optimal support to national objectives with quicker and better products. Accordingly, it will be structured to respond vigorously and coherently to Federal, state, and local requirements for organized and accurate spatial data, whether presented graphically on conventional map and chart formats or in digital form via computer tape or printout. By exercising its new capabilities and by taking aggressive community leadership, we expect the Federal Survey Administration to reduce expenditures for overhead and slow down and then stop the

uncoordinated growth of MC&G activities and eventually bring about reduction in single-purpose programs. The potential for achieving these reductions through strong central management forms the basis for our belief that overall savings will result from reorganization. More specifically, the reorganization we propose will provide the following management improvements over the status quo:

- Photo collection will be integrated efficiently and effectively in production of standardized multiuse products required by the Federal Government.

- Overlapping operations will be eliminated.

- Expensive equipment that is most cost effective at full capacity, such as computers, printing presses, and precise measuring and plotting instruments, will be used more efficiently.

- Expertise in research and development will be pooled, and effective interface with DOD advanced technology centers can be achieved.

- Projects requiring multidiscipline skills -- such as those benefiting from a combination of control surveys, conventional mapping, and soils and geologic surveys -- can be planned and coordinated.

- Printing and distribution can be set up as services of common concern and carried on more effectively and at lower cost with greater convenience to Federal users and the public.

- Personnel with like skills can be interchanged among related programs under single management to improve flexibility of staff and operations as needs change.

- Management functions, such as budgeting, planning, personnel administration, procurement, and accounting, will be streamlined to provide administrative efficiencies and savings over the long run.

- A single data/information service will access, reference, evaluate, and collect the spatial data now collected and maintained disparately by a number of agencies into a standard system easily accessible for current multipurpose use or for new emerging applications.

ORGANIZATIONAL STRUCTURE

To take advantage of existing capabilities, like skills, compatible methodologies, and similar functions and at the same time accomplish program improvements suggested earlier, we recommend a management structure within the Federal Survey Administration consisting of five major centers -- National Charting, National Mapping, National Survey, Geographic Information, and Printing and Distribution.

The following discussion outlines the principal objectives of these centers and indicates the entities and functions of existing organizations which would be transferred to the Federal Survey Administration.

National Charting Center

Objectives	Transfers
o Produce civilian aeronautical charts and related data for safe, efficient management and use of the National Airspace.	NOAA/NOS -- Aeronautical charting and related cartographic activities.
o Produce the national series of nautical charts and related information for safe and efficient use of the Nation's waterways and coastal waters.	NOAA/NOS -- Nautical chart production activities.
o Provide marine geophysical and geological information through mapping and data reports of the U.S. Continental Shelves and selected deep ocean areas and the Great Lakes.	NOAA/NOS -- Bathymetric and geophysical activities. GS/Geologic Division -- Marine geophysical and geological activities.

Objectives	Transfers
o Provide graphic and descriptive coastal boundary determinations, tidal datums, hydrodynamic descriptions, prediction services and related information of the coastal zone and the Great Lakes	NOAA/NOS -- Coastal mapping and oceanographic activities. GS/Water Resources Division -- Coastal tide gauge network activities.
o Provide marine hydrographic, bathymetric, geophysical, and geologic data and related products through collection, exchange, archiving, and dissemination services.	NOAA/NOS -- Marine data services. NOAA/EDS -- Marine geophysical data services. GS/Geologic Division -- Marine geologic data services.
o Provide planning, equipment engineering and testing, computer services, and logistic support for the National Charting Center's vessels and operate the Atlantic and Pacific ship base facilities.	NOAA/NOS -- Fleet operations services in support of the Center's objectives.
o Provide research and development support to the Center's activities.	NOAA/NOS -- Engineering development labs and support services.

National Survey Center

Objectives	Transfers
o Establish and maintain the National Geodetic Networks (vertical and horizontal) and related surveys for optimum multi-purpose use. Conduct geodetic measurements to support earth-physics-related activities.	NOAA/NOS -- Horizontal and vertical control and earth physics activities. GS/Topographic Division -- Horizontal and vertical control survey activity. BLM, BPA, BIA, BR, SCS, FS, TVA, HUD, and CE -- Horizontal and vertical surveys which are systematic in nature and either presently or with little additional effort could contribute to the national networks.
o Establish and maintain basic cadastral network in conjunction with the National Geodetic Program and conduct network cadastral surveys in support of Federal land management.	BLM, CE, BR, FS, TVA, MRC and BSFW -- Those cadastral survey activities which contribute to the basic cadastral reference network (i.e., cadastral survey measurement where network is not complete or project area exceeds 36 square miles).
o Maintain an active Center for accession, storage, and dissemination of data on horizontal and vertical control, and related activities.	NOAA/NOS -- Geodetic and related data accession and dissemination activities (i.e., Geodetic Data Center). GS/Topographic Division -- Horizontal and vertical control data activities within the Map Information Office. BR, BSFW, FS, TVA, and CE -- Activities associated with accession, storage, and retrieval of network-quality control data.

Objectives

- Conduct research and development activities to support the Survey Center's objectives.

Transfers

NOAA/NOS -- Geodetic R&D activities.
GS/Topographic Division -- Horizontal and vertical control R&D activities.

National Mapping Center

Objectives

- Provide the national series of topographic maps, other planimetric base maps, and special products for multipurpose use. Support other agencies through cartographic, photogrammetric, and related services.

Transfers

GS/Topographic Division -- Photogrammetric, cartographic, and map-finishing activities (map production).
GS/Geologic Division -- Cartographic support for geologic mapping.
GS/Water Resources Division -- Cartographic support for hydrologic mapping and flood-insurance mapping activities.
GS/Publications Division -- Branch of Technical Illustrations.
BLM -- Base-map production (1 in. to 1 mi. series).
BIA -- Base-map production (1 in. to 2 mi. Road Atlas).
SCS -- Soils base-map production; other base-map production.
FS -- Base-map production (1 in. to 2 mi. and 1:24,000 scale).
SESA/Census -- Metropolitan series map production.
HUD -- Urban mapping series.
CE -- 1:24,000-scale map production.
MRC -- 1:62,000 map production.
EPA -- Drainage digitization, etc.
TVA -- 1:24,000 revision, other base-map production.

Objectives	Transfers
o Collect and process aerial photography for the Mapping Center's operational needs and provide aerial photography to meet other agency needs for systematic (large-area) photo coverage where multipurpose use is anticipated.	GS/Topographic Division -- aerial photography collection and initial processing. ASCS -- Aerial photo collection and processing. SCS, FS, CE, Census, BR, BLM, BIA, EPA, NASA, and TVA -- Domestic systematic photo coverage activities where multipurpose use can be economically achieved.
o Provide research and development support for the Center's activities.	GS/Topographic Division, Forest Service, and Census -- Photogrammetry, cartography, and map finishing R&D activities related to the Center's production activities.
o Operate an active map data file to support the Center activities.	GS/Topographic Division, BLM, Census, and TVA -- Map data center activities which support the objectives of the Mapping Center.

Geographic Information Center

Objectives	Transfers
o Establish and maintain a current, centralized information center on: (1) all collected and processed domestic imagery from Federal sources; (2) all domestic geodetic control and related survey data; (3) domestic maps, charts, and related products produced by or procured with Federal funds; and	GS/Topographic Division -- MIO/NCIC activities related to imagery references and accessing and map and chart library functions. GS/EROS -- EROS Data Center activities. Interior/RALI -- All functions related to MC&G data. NOAA/NOS -- Marine data information activities. NOAA/EDS -- Marine geophysical data activities.

Objectives	Transfers
(4) marine hydrographic, bathymetric, geophysical, and geological data in civilian areas of interest.	ASCS -- Imagery information functions. GS/Topographic Division -- Geographic names staff support.

Printing and Distribution Center

Objectives	Transfers
O Provide for printing and related processing used in the publication of all MC&G products prepared by FSA and cooperating agencies. Maintain a distribution network in conjunction with Federal outlets, regional distribution centers, and commercial agents for MC&G products.	GS/Publications Division, NOAA/NOS, Census, SCS, FS, and TVA -- Printing and distribution activities related to MC&G products.

Plans and Requirements Staff

In addition to the five major centers, the Federal Survey Admiinistration must provide a strong, vigorous, multidisciplined Plans and Requirements Staff which would determine equitable allotments of resources for conducting national domestic MC&G programs. It is safe to say that regardless of how efficient and dedicated FSA may become, some requirements will not be met within available resources; therefore, the Plans and Requirements Staff working hand-in-glove with all Federal users must:

- Assemble, review, validate, and rank in priority domestic MC&G requirements of the Federal agencies in accordance with overall requirements and priority guidance established by OMB.

- Prepare an integrated requirements and priorities list which will become the basis for allocation of FSA resources. This list will be available to user agencies and OMB for review and comment. It will provide a basis for appeal to OMB if user requirements are not being met.

- Continually review all existing Federal MC&G products and their specifications to assure consonance with ever changing Federal program requirements.

- Provide technical assistance to Federal users in formulating and defining technical MC&G requirements parameters.

- Insure timely response to the MC&G requirements within the limits of resources and provide alternative means of meeting needs which cannot be accomplished within allotted resources.

- Submit to OMB timely reports stating the agreements and disagreements concerning intragovernmental actions including appropriate recommendations and associated impacts.

- Seek out and identify duplication and unwarranted products and services as well as recommend to OMB modification of MC&G activities where overall government needs dictate.

ORGANIZATION PLACEMENT

Because of the particularly close relationship MC&G has to the functions and programs dealing with conservation and management of natural resources, land use, public-land management, preservation of the environment, including the coastal and nearshore ocean areas, which the President would assign to the proposed Department of Energy and Natural Resources (DENR), we recommend an organizational structure for the Federal Survey Administration that could fit readily into DENR.

Realizing, however, that it could be some time before the President's reorganization is implemented and not wishing to delay establishment of the new MC&G agency, we have also considered the options of placing it in existing departments or as a separate agency. Seven options were considered for placement of the Federal Survey Administration as follows:

- o Independent agency.
- o In DENR as a separate administration.
- o In DENR under OAESA (the President's plan transfers GS and NOAA as entities to DENR and establishes an Oceanic Atmospheric, and Earth Science Administration).
- o In Interior as a separate administration.
- o In Interior under GS.
- o In Commerce as a separate administration.
- o In Commerce under NOAA.

Two options splitting the functions given to the Federal Survey Administration were also considered:

- o Marine functions in NOAA -- all other functions in Interior.

- o Same as above, but with Interior providing cartographic, reproduction, and distribution services for marine programs.

The placement options of FSA with major advantages and disadvantages are listed below.

Independent Agency (Option 1)

Advantages

- o Focuses national interest and elevates status to provide maximum visibility and authority to deal directly with OMB, Congress, and departments on matters of program levels and national priorities.

- o Places the administrator in better position to evaluate overall requirements, balance conflicting demands, and fairly allocate limited resources as well as coordinate appropriate MC&G activities outside the Agency.

- o Provides more latitude in bringing freshness of outlook and freedom of action diffult to achieve in an existing department.

Disadvantages

- o Inconsistent with President's program for reducing number of executive departments.

- o Intensity of interest not sufficient to justify continuous attention at the Presidential level.

- o Too small for self-sufficient independent agency -- costs would be higher for administrative support functions normally provided by departments or bureaus.

- Insulation of MC&G program from all users and related programs could result in a self-serving agency.

- Requires legislation.

In DENR as a Separate Administration (Option 2)

Advantages

- Consistent with President's concept for executive reorganization.

- Provides nearly the same advantages as independent agency in terms of program visibility, authority, and management flexibility without the disadvantages of a small agency operating at the Presidential level.

- Provides level of management commensurate with intensity of national interest, in the department whose programs require most MC&G support.

- Can be accomplished through same executive reorganization plan implementing DENR.

Disadvantages

- Would be small compared to other DENR administrations -- less than half as large as the smallest now proposed.

- Marine program management located in two administrations.

- Because FSA performs a service function, it would be out of place in a department organized along program lines.

In DENR under OAESA (Option 3)

Advantages

- Most consistent with proposed DENR organization plan.

- Maximum combination of like activities with least disruption.

- Separate agency administrative support not required.

- Marine programs within DENR in same administration.

Disadvantages

- Provides fewer advantages than options 1 and 2 in terms of program enhancement, authority, and management flexibility.

- Adds a management layer between FSA and other Federal agencies requiring MC&G products.

- Preferential support to OAESA programs is likely.

In Interior as a Separate Administration (Option 4)

Advantages

- Provides some of the benefits listed for a separate administration in DENR in terms of program visibility, authority, and management flexibility.

- Most FSA land-mapping and surveying programs fit overall department mission.

- Size compatible with other departmental bureaus.

Disadvantages

- Would fragment marine activities -- some of the marine programs would be in FSA and the remaining marine programs and the ship operations would be in NOAA.

- Tendency to subordinate MC&G to other departmental programs, thereby reducing responsiveness and fostering uncontrolled growth of MC&G activities in other agencies.

- Possibility of favoring land mapping and surveying over marine program.

In Interior under GS (Option 5)

Advantages

- Locates functions in an existing agency having major mapping and surveying programs.
- GS could provide administrative support at less cost than required for a separate administration.
- Least disruptive of activities in GS.

Disadvantages

- Has most of the disadvantages of a separate administration in Interior (Option 4) plus:
  - Places new agency under non-MC&G manager; would tend to subordinate national MC&G program to problem-oriented earth-science management.
  - Adds a management layer between FSA and other Federal agencies requiring MC&G products.

In Commerce as a Separate Administration (Option 6)

Advantages

- Provides some of the benefits listed for a separate, independent administration in DENR in terms of program visibility, authority, and management flexibility.
- Allows more effective interface of MC&G with related marine activities and survey-ship operations.
- Size compatible with other department bureaus.

Disadvantages

- o Commerce mission not related to most MC&G programs.
- o Further separates land mapping from major land-management and resource-program agencies.
- o Tendency to subordinate MC&G to other departmental programs, thereby reducing responsiveness and fostering uncontrolled growth of MC&G activities in other agencies.

In Commerce under NOAA (Option 7)

Advantages

- o Locates functions in an existing agency having major surveying and charting programs.
- o Least disruptive to NOAA MC&G program and interfaces.
- o Marine activities not fragmented.
- o NOAA could provide administrative services at less cost than required for a separate agency.
- o Provides more program visibility, authority, and management flexibility than any other logical Federal bureau because of NOAA's elevated position in Commerce. (NOAA's internal organization now structured to accommodate management of large, complex, diverse programs.)

Disadvantages

- o Because NOAA is subordinated to Commerce, this option has same disadvantages as a separate administration in Commerce (Option 6), plus:
  - Another management layer between FSA and outside agencies.

- Possibility of favoring atmospheric and marine sciences over land surveying and mapping.

Split Functions -- Marine in NOAA/All Other in Interior (no FSA)

Advantages

- o Leaves MC&G marine programs and ship operations with related functions in NOAA.
- o More land-related programs assigned to department with major land and resources responsibility.
- o Least disruptive to existing NOAA and GS programs and interfaces.

Disadvantages

- o No single central management structure.
- o Authority and responsibility for MC&G programs remain divided.
- o Destroys opportunities for effective cross-program analysis, design, and judgment.
- o Budget process remains fragmented.
- o Flexibility of personnel and equipment not optimum.
- o MC&G interface with DOD is diffused.

Marine Programs in NOAA/All Other MC&G Programs in Interior, with Interior Providing Cartographic, Reproduction and Distribution Services for Marine Programs (no FSA)

Advantages

- o Preserves most advantages of FSA enumerated on pages 172-174.
  - Assigns strong authority and responsibility over all MC&G except marine programs and coastal-zone mapping.
  - Maintains large resource base under single management in Interior.
  - Allows optimum use of most common skills and expensive equipment.
  - Retains central point for product and data distribution.
  - Doesn't fragment marine programs.
  - Consistent with the approach of a central agency providing cartographic, reproduction, and distribution services for other programs such as soils, geology, and census.

Disadvantages

- o No central management or budget structure.
- o Continues dichotomy in coastal-zone mapping.
- o Does not take advantage of all MC&G commonalities.
- o Requires strong coordination mechanism between NOAA and Interior agency.
- o MC&G interface with DOD is diffused.